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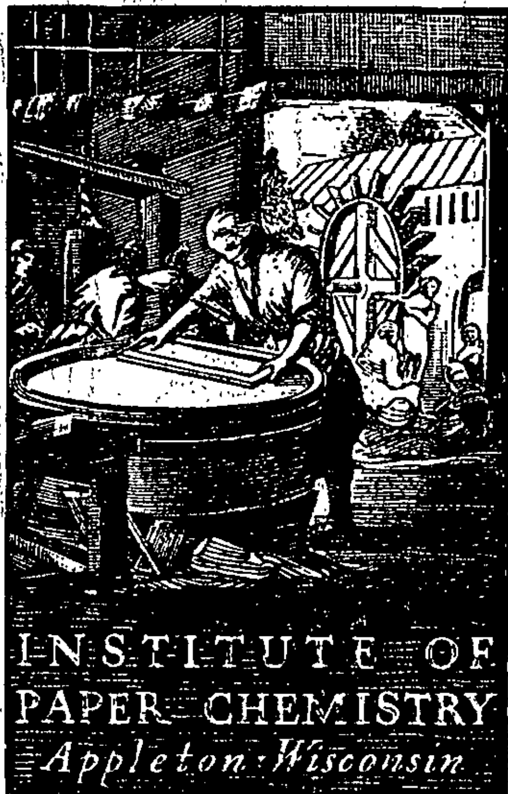

COMPARATIVE PERFORMANCE STUDY

Project 2392

Report Three

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

May 1, 1965

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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TABLE OF CONTENTS

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SUMMARY

In the free world today there are two primary producing areas of virgin containerboard - namely, the United States and the Scandinavian countries These "producers" compete to a greater or lesser degree in practically all world containerboard markets; however, the largest joint market is Western Europe. These two containerboard-producing areas practice conflicting manufacturing philosophies, both undoubtedly oriented toward the most economical manufacture and distribution of their product. The two philosophies differ mainly in respect to the importance of weight and bursting strength of the components to box quality

The Scandinavian countries, because of advantageous wood species, manufacturing economies specific to their area, and less restrictive regulatory specifications in certain Western European countries, notably West Germany, manufacture unbleached kraft containerboard at a lower weight and higher bursting strength than is practiced with corresponding board made in this country. In effect, the Scandinavian philosophy advocates a lighter weight container in contrast to United States practice and implies that the container weight can be reduced with impunity provided the lower weight is compensated for by an increase in bursting strength In contrast, the philosophy practiced by U S manufacturers suggests that a quality box requires a certain minimum weight of fiber, if more substance (fiber) is used, the bursting strength of the linerboard need not be as high as that associated with the lighter weight Scandinavian linerboard.

The manufacturing philosophy practiced by the Scandinavian containerboard manufacturers places a burden on U.S exportation of linerboard to those countries where weight is not considered a factor in containerboard quality

U S linerboard manufacturers can make linerboard to the same specifications as Scandinavian linerboard, however, this would require modifying current manufacturing practice — e.g , more refining, slower speeds, etc. — which would adversely influence costs

In order to determine the comparative performance of combined board and boxes made with European and domestic kraft linerboards, a study was initiated at The Institute of Paper Chemistry by the Fourdrinier Kraft Board Institute, Inc. The study involved the fabrication of two Scandinavian and one domestic linerboard at each of four nominal grade weight levels with 23-lb. European and 26-lb semichemical corrugating medium into A- and B-flute combined board and boxes under normal but controlled conditions of fabrication using starch as the adhesive The European linerboards — i.e., 25.6, 30.7, 35.8, and 41 0-lb. — were made by Enso Gutseit (Finland) and Svenska Cellulosa (Sweden) The 23-lb. semichemical medium was made by Fiskeby. Also, a few trials were made in which a 26-lb European semichemical corrugating medium (Finnkarton) was fabricated with domestic linerboards into combined board and boxes The domestic linerboards — i.e., 26, 33, 38, and 42.0-lb. — were obtained from a member company of Fourdrinier Kraft Board Institute, Inc. and the quality manufacturing specifications were those corresponding to the current industry average quality to be expected for each grade weight.

The combined boards and boxes resulting from the fifty-two experimental material combinations used in this study, together with samples of the components used in each run, were evaluated for performance at 50 ± 2% relative humidity and 73 ± 3 5°F (standard conditions in U S) and 65% relative humidity at 68°F. (standard conditions in Europe) It should be borne in mind in interpreting the results that the comparative performance is based on the results of two European and one domestic sample of linerboard at each of the grade weight levels The results, therefore, represent comparative performance to be expected only to the extent that the linerboards are representative at each grade weight level.

The following conclusions are based on the composite average performance at each grade weight level

1. Comparative Performance at 25 6, 26 0-lb Grade Weight Level:

   A. The European linerboards at this grade weight averaged 3 to 5% lower than U S. linerboards in basis weight but 37 to 53% higher in bursting strength. The difference in nominal basis weight is only about 1.5%. The difference in basis weight of the linerboard is manifested in the combined board weight The combined boards made with 26-lb. U S linerboard were 2 to 4% higher in weight than the corresponding boards made with European linerboards.

   B Box Performance:

      (1) Boxes made with U.S linerboards, in general, exhibited 2 to 7 5% higher top-load box compression than the boxes fabricated with European linerboards The greatest difference was between U S. and Svenska Cellulosa boxes Because of the lower weight of the European linerboards, the above differences, when computed on a unit weight basis, are reduced and are probably not significant

      (2) In general, end-load box compression averaged slightly higher for boxes made with U S linerboard than for boxes made with European linerboards, however, the differences are not considered significant As in the case of top-load compression, the differences are reduced when computed on a unit weight basis, and are too small to be considered significant

(3) Boxes made with U S. linerboard averaged slightly lower in corner drop performance (3 to 3.5%) than boxes made with Enso Gutseit linerboard but higher (9 to 24%) than boxes made with Svenska Cellulosa linerboard. In only one case – i e., Svenska Cellulosa boxes at 50% relative humidity – were the differences significant. The same general trend was noted when corner drop performance was computed on a unit weight basis.

(4) The drum performance of boxes fabricated with U.S. linerboard averaged 3 to 10% higher than that of boxes made with Enso Gutseit linerboard and 12 to 16% higher than that of boxes made with Svenska Cellulosa linerboard, however, these differences are not considered significant because of the variability associated with the drum test of these boxes When computed on a unit weight basis the differences decrease

(5) On an over-all box performance basis the box results indicate that at the 25 6, 26.0-lb. linerboard weight level, boxes made with U.S. linerboard may be expected to give slightly higher top-load compression, about equal end-load compression, and also about equal rough handling as measured in terms of corner drop and drum tests When compared on a unit weight basis, the results indicate that there is probably no significant difference in box compression or rough handling between boxes made with U S. and European linerboards.

C. Combined Board Performance·

(1) In addition to the difference in basis weight and bursting strength noted above, the combined boards made with U.S linerboard averaged higher in caliper, puncture, torsion tear, edgewise compression,

flat crush, and pin adhesion than combined boards made with European linerboards

(2) The combined boards made with U S. linerboard were 35 to 65% lower in bursting strength and 5 to 14% lower in flexural stiffness (expressed as geometric mean) than the combined boards made with European linerboards

D Linerboard Characteristics

In addition to the differences in basis weight and bursting strength noted above, the following differences were also noted

(1) The U.S. linerboard exhibited higher caliper, tearing strength, torsion tear, puncture, Taber stiffness, and I.P.C. bond strength than the European linerboards

(2) The U.S. linerboards exhibited lower bursting strength (37 to 53%), density, modified ring compression, tensile strength, stretch, modulus of elasticity, and tensile energy absorption (T E.A) They were also rougher and more porous than European linerboard

2 Comparative Performance at 30 7, 33 C-lb Grade Weight Level

A. The U S linerboard at this grade weight level was 9 to 12% higher in basis weight and 6 to 18% lower in bursting strength than the corresponding European linerboards The observed difference in basis weight is considerably greater than the 7 0% computed on the basis of the difference in nominal weight The differences in linerboard weight and bursting strength manifest themselves in a higher combined board (5 to 7%) basis weight and lower (4 to 22%) bursting strength for the combined boards made with U.S linerboards

B. Box Performance.

(1) The boxes made with 33.0-lb. U S linerboard exhibited top-load compression results which were significantly lower (1 6%) at 50% R H but not significantly different at 65% R H. than the boxes made with Enso Gutseit linerboard The boxes made with Svenska Cellulosa linerboards gave top-load compression results not significantly different from boxes made with U S. linerboard. Because of the substantially lower basis weight of the combined board, the boxes made with European linerboards gave significantly higher (4 to 7%) top-load compression than boxes made with U.S. linerboard when computed on a unit weight basis.

(2) The end-load box compression strength of boxes made with U S. linerboard was 5 to 7% higher than that of boxes fabricated with Enso Gutseit linerboard but 1 to 3% lower than that of boxes made with Svenska Cellulosa linerboard The differences noted for the boxes made with Enso Gutseit linerboards are significant whereas those for the boxes made with Svenska Cellulosa linerboards are not significant When the end-load compression results are computed on a unit weight of combined board basis, there is no significant difference between boxes made with U.S. and Enso Gutseit linerboards, however, on this basis, the boxes made with Svenska Cellulosa linerboards are significantly higher (4 to 7%) than boxes fabricated with U.S linerboard

(3) In general, the corner drop performance of boxes made with Enso Gutseit linerboard was not significantly different from the performance of boxes made with U.S. linerboard On the other hand, the corner drop performance of boxes made with Svenska Cellulosa linerboard

was significantly higher (17 to 18%) than the drop performance of boxes made with U.S. linerboard. On a unit weight of combined board basis, boxes made with European linerboard exhibited higher drop performance (Enso Gutseit, 5 to 6%; Svenska Cellulosa, 24 to 27%) than boxes made with U.S. linerboard. The differences noted for the boxes made with Enso Gutseit linerboards are not significant whereas those for boxes made with Svenska Cellulosa linerboards are.

(4) The drum performance of boxes made with U.S. linerboard in general was higher than that of boxes made with Enso Gutseit linerboard but slightly lower than that for boxes made with Svenska Cellulosa linerboard. The difference noted for Enso Gutseit boxes is significant whereas the difference for Svenska Cellulosa boxes is not. Computing the performance on a unit weight basis has the effect of decreasing the difference for Enso Gutseit boxes and increasing the differences for Svenska Cellulosa boxes.

(5) On an over-all basis the box results obtained at the 30.7, 33.0-lb. grade weight level indicate that boxes made with U.S. linerboard give about the same top-load box compression, equal (Svenska Cellulosa boxes) to higher (Enso Gutseit boxes) end-load compression, equal (Enso Gutseit boxes) to lower (Svenska Cellulosa boxes) corner drop performance, and higher (Enso Gutseit boxes) to equal (Svenska Cellulosa boxes) drum performance compared with boxes made with European linerboards.

When box performance is computed on a unit weight combined board basis, the boxes made with U.S. linerboard are lower (4.5 to 7.5%) in top-load compression, equal in end-load compression, equal in corner drop and higher in drum performance when compared with boxes made with Enso Gutzeit linerboard. On the other hand, boxes made with Svenska Cellulosa linerboards gave higher top-load compression (6 to 7%), higher end-load compression (4 to 7%), higher corner drop performance (24 to 27%), and higher drum performance (15 to 16%) than boxes made with U.S. linerboards. All the differences on a unit weight combined board basis are considered significant with the possible exception of the differences for the drum performance tests.

C. Combined Board Performance:

(1) In addition to the differences in basis weight and bursting strength previously noted, the combined board fabricated with U.S. linerboard exhibited higher caliper, puncture, torsion tear, edgewise compression strength, and pin adhesion than combined boards fabricated with European linerboards.

(2) The combined boards made with U.S. linerboards gave lower values of bursting strength (4 to 22%) and flat crush than corresponding combined boards made with European linerboards.

D. Linerboard Characteristics

(1) Enso Gutzeit linerboard exhibited lower basis weight, caliper, tearing strength, torsion tear, puncture, ring compression, Taber stiffness, machine-direction stretch, and machine-direction I.P.C. bond strength than U.S. linerboard. On the other hand, Enso Gutzeit linerboard displayed higher bursting strength (approximately 18%) tensile strength, cross-machine stretch, modulus of elasticity, T.E.A., and cross-machine I.P.C. bond strength than U.S. linerboard.

(2) Svenska Cellulosa linerboard displayed lower basis weight, caliper, apparent density, tearing strength, torsion tear, puncture, ring,

compression, machine-direction stretch, and machine-direction T.E.A., than U.S. linerboard. In contrast, Svenska Cellulosa linerboard exhibited higher bursting strength (6 to 12%) machine-direction Taber stiffness, tensile strength, cross-machine stretch, machine-direction modulus of elasticity, cross-machine T.E.A., and I.P.C. bond strength than U.S. linerboard.

(3) Enso Gutseit linerboard was less porous, not as smooth and not as water resistant as the U.S. linerboard. The Svenska Cellulosa linerboard was more porous, less smooth and less water resistant than the U.S. linerboard.

3. Comparative Performance at 35.8, 38.0-lb. Grade Weight Level:

A. The U.S. linerboard exhibited 4 to 8% higher basis weight but 37 to 40% lower bursting strength than the European linerboard. These differences are reflected in a higher combined board weight (3 to 5%) and a lower bursting strength (18 to 35%) for the combined board made with U.S. linerboard.

B. Box Performance:

(1) Boxes made with U.S. linerboard gave significantly lower top-load compression (approximately 7.0%) than boxes made with Enso Gutseit linerboard. In general, the same trend was noted for boxes made with Svenska Cellulosa linerboard; however, the differences were considerably less (1 to 4%). When considered on a unit weight basis, boxes made with Enso Gutseit linerboard gave 11 to 13% higher top-load compression and boxes made with Svenska Cellulosa linerboard 5 to 10% higher top-load compression than boxes made with U.S. linerboard.

(2) Boxes made with Enso Gutseit linerboard exhibited 2 to 6% higher end-load compression and boxes fabricated with Svenska Cellulosa linerboard 7 to 9% lower end-load compression than boxes made with U.S. linerboard. The same trend is obtained on a unit weight basis. However, on a unit weight basis the differences between boxes made with U.S. and Enso Gutseit linerboards increase (6 to 10%), whereas the difference between boxes made with U.S. and Svenska Cellulosa linerboards decrease (2 to 5%).

(3) The corner drop results for boxes made with U.S. linerboard are significantly higher (14.3%) at 50% R.H. but not significantly different at 65% R.H. than boxes made with Enso Gutseit linerboard. On a unit weight of combined board basis, there appears to be no significant difference at either humidity level. In contrast, the boxes made with Svenska Cellulosa linerboard exhibited higher (7 to 24%) corner drop results than the corresponding boxes made with U.S. linerboard at both 50% and 65% R.H. However, only the results at 65% R.H. appear to be significant. The same general trend is evident when the results are considered on a unit weight of combined board basis.

(4) The drum performance of boxes fabricated with U.S. linerboard was significantly higher (18 to 20%) than the corresponding performance for boxes made with Enso Gutseit linerboard but not significantly different from the performance for boxes made with Svenska Cellulosa linerboard. The same general trend is observed when the results are considered on a unit weight of combined board basis.

(5) On an over-all basis boxes fabricated with U.S. linerboard appear to give lower top-load compression, slightly lower end-load compression,

slightly higher corner drop, and higher drum performance than boxes made with Enso Gutseit linerboard. The boxes fabricated with Svenska Cellulosa linerboard exhibited slightly higher top-load compression, lower end-load compression and about the same drop and drum performance when compared with boxes made with U.S. linerboard.

C. Combined Board:

(1) The combined boards fabricated with U.S. linerboards averaged about 3 and 5% higher, respectively, in basis weight than combined boards made with Enso Gutseit and Svenska Cellulosa linerboards.

(2) The bursting strength of the combined board made with 38-lb. U.S. linerboard was 18 to 35% lower than that of the corresponding combined boards made with European linerboards.

(3) In general, combined board made with U.S. linerboard exhibited higher caliper, puncture, torsion tear, flat crush, and pin adhesion than the corresponding boards made with European linerboards. On the other hand, the combined board made with U.S. linerboard was lower in cross-machine edgewise compression and flexural stiffness (expressed as geometric mean). The machine-direction edgewise compression results on boards made with Enso Gutseit linerboard were higher than the corresponding results for U.S. boards whereas the results on Svenska Cellulosa boards were lower.

D. Linerboard Characteristics:

(1) The 38-lb. nominal grade weight U.S. linerboard averaged approximately 5% higher in basis weight than the corresponding Enso Gutseit linerboard and about 7% higher than the corresponding Svenska Cellulosa linerboard.

(2) The bursting strength of the U.S. linerboard was approximately 38 to 40% lower than that of the European linerboard even though the basis weight favored the U.S. linerboard.

(3) The U.S. linerboard was higher in tearing strength, torsion tear, and puncture. In addition to the foregoing, Enso Gutseit linerboard was higher in ring compression, cross-machine Taber stiffness, tensile strength, modulus of elasticity, T.E.A., I.P.C. bond strength, and about equal in water resistance. The Svenska Cellulosa linerboard was higher in cross-direction ring compression, tensile strength, stretch, modulus of elasticity, T.E.A., and I.P.C. bond strength and about equal in water resistance.

(4) The European linerboards were more dense and hence less porous than the U.S. linerboard. The Enso Gutseit linerboard was not as smooth as the U.S. linerboard whereas the Svenska Cellulosa linerboard was smoother.

4. Comparative Performance at the 41.0, 42.0-lb. Grade Weight Level:

A. The 42-lb. nominal grade weight U.S. linerboard was approximately 3 and 8% higher in basis weight, respectively, than the Enso Gutseit and Svenska Cellulosa linerboards. As would be expected, the basis weight of the combined boards made with U.S. linerboard averaged 2.0 and 4.8% higher, respectively, than the combined boards made with Enso Gutseit and Svenska Cellulosa linerboards. On the other hand, the bursting strength of the combined board made with U.S. linerboard was 23 to 30% lower than that of the combined boards fabricated with European linerboards.

B. Box Performance:

(1) The boxes fabricated with U.S. linerboard gave significantly lower top-load compression (8.7 to 11.2%) than boxes made with Enso Gutseit linerboard. When compared to boxes made with Svenska Cellulosa linerboard, the results on the U.S. boxes were only slightly lower. When computed on a unit weight of combined board basis, the boxes made with U.S. linerboard were significantly (6 to 13%) lower than boxes made with European linerboards.

(2) In general, end-load compression on boxes fabricated with U.S. linerboard was slightly lower than that on boxes made with European linerboard; however, the differences are not significant in most cases. When calculated on a unit weight of combined board basis, the boxes made with European linerboard exhibited significantly higher end-load compression performance.

(3) In general, the corner drop performance for boxes made with U.S. linerboard is slightly lower than for boxes made with European linerboard; however, the differences are not significant in most cases. The same trend was noted on a unit weight of combined board basis.

(4) In general, there was no significant difference in drum performance between boxes made with domestic and European linerboards. The same trend was noted when the results were considered on a unit weight of combined board basis.

(5) On an over-all basis, boxes made with U.S. linerboard gave lower top-load compression, approximately equal end-load compression, and approximately equal corner drop and drum performance when compared with boxes made with Enso Gutseit linerboard. Boxes made

with Svenska Cellulosa linerboard were about equal in top-load compression, end-load compression, corner drop, and drum performance compared with boxes made with U.S. linerboard.

C. Combined Board:

(1) In addition to higher basis weight and lower bursting strength, the combined board made with U.S. linerboard was about equal in caliper and flat crush but higher in puncture, torsion tear, and pin adhesion when compared with combined board made with European linerboards. In contrast, combined boards made with European linerboards were higher in machine- and cross-machine edgewise compression and flexural stiffness (geometric mean).

D. Linerboard Characteristics:

(1) In addition to higher basis weight, the U.S. linerboard exhibited 20 to 27% lower bursting strength than the European linerboards.

(2) In general, the U.S. linerboard was higher in caliper, tearing strength, torsion tear, stretch, and machine-direction I.P.C. bond strength than the Enso Gutseit linerboard. On the other hand, the Enso Gutseit linerboard was higher in ring compression, Taber stiffness, tensile strength, modulus of elasticity, T.E.A., and cross-machine I.P.C. bond strength than U.S. linerboard. The Enso Gutseit linerboard tended to be slightly more dense, much less porous, rougher and slightly better sized than the U.S. linerboard.

(3) The U.S. linerboard was slightly higher in caliper, density, tearing strength, torsion tear, puncture, and machine-direction stretch than Svenska Cellulosa linerboard. On the other hand, the Svenska Cellulosa

linerboard was higher in ring compression, Taber stiffness, tensile, cross-machine stretch, modulus of elasticity, T.E.A., and I.P.C. bond strength than the U.S. linerboard. The Svenska Cellulosa linerboard was less dense and less porous but rougher than the U.S. linerboard and not as well sized as the U.S. linerboard.

5. General Conclusions:

A. The comparative performance of combined board and boxes fabricated with European linerboard was such that the competitive potentials of European linerboard cannot be disregarded.

B. The European linerboard appears to be made from a furnish consisting mainly of Scotch pine, refined to a lower freeness and shorter average fiber length and presumably made at a slower speed than U.S. linerboard.

C. European linerboard is made at a lower basis weight but substantially higher bursting strength than the corresponding grade weights of U.S. linerboard.

D. The superiority of the European linerboards in bursting strength is not reflected in a correspondingly high box performance relative to U.S. linerboard.

E. Box compression is shown to be far better related to combined board edgewise compression and flexural stiffness than to bursting strength.

F. It is believed that the properties of European linerboard responsible for its competitive potential is not bursting strength but the level to which the more basic mechanical properties such as edgewise compression, modulus of elasticity, tensile strength, etc., develop concomitantly with bursting strength.

G. The rough handling performance of boxes made with European linerboard was considerably better than would normally be anticipated from the tearing strength characteristics of the linerboard and corresponding combined board. In terms of rough handling, the lower tearing strength is compensated for, in part at least, by substantially higher tensile and energy absorption characteristics compared to U.S. linerboard.

H. In general, the combined boards made with European linerboards exhibited lower pin adhesion strength. This is believed to be due to the generally less porous structure of the European linerboard and hence it would be expected that greater difficulty would be encountered with bonding on the corrugator with European linerboard especially at the higher speeds.

I. As would be expected, the test results at 65% R.H. (European standard conditions) were lower for those tests involving stiffness but higher for those involving energy absorption or work than the results at 50% R.H. (U.S. standard conditions). The effect of relative humidity was about the same for European and U.S. linerboards.

J. On the basis of the coefficients of variation which were determined for a selected number of test properties in order to compare the uniformity of the U.S. and European linerboards, it was concluded that the U.S. linerboards were generally slightly more uniform than the European linerboards.

6. Comparative Performance of Boxes Made with European Linerboard

A Box Performance:

(1) At the 25.6-lb. grade weight level, boxes made with Enso Gutseit linerboard gave equal or slightly higher top-load compression, lower end-load compression, and slightly higher corner drop and drum performance than the boxes made with the corresponding grade weight of Svenska Cellulosa linerboard

(2) At the 30.7-lb grade weight level, boxes made with Enso Gutseit linerboard gave equal top-load compression, lower end-load compression, lower corner drop and drum performance than boxes made with the corresponding grade weight of Svenska Cellulosa linerboard.

(3) Boxes made with Enso Gutseit 35.8-lb. linerboard gave slightly higher top- and end-load compression, but lower corner drop and drum performance than boxes made with the corresponding grade weight of Svenska Cellulosa linerboard

(4) When the performance of boxes made with 41.0-lb European linerboards is considered, the boxes made with Enso Gutseit linerboard gave slightly higher top- and end-load compression and about the same corner drop and drum performance when compared with boxes made with the corresponding grade weight of Svenska Cellulosa

(5) On an over-all basis, boxes made with Enso Gutseit linerboard tended to give slightly higher top-load compression at all grade weight levels, slightly lower end-load compression at the 25.6 and 30.7-lb grade weight level but slightly higher end-load at the 35.8 and 41.0-lb grade weight levels, and equal to lower corner drop and drum performance when compared with the corresponding results for boxes made with Svenska Cellulosa linerboards

7. Comparative Performance of Combined Board and Boxes Made with 23-lb. and 26-lb. European and 26-lb. U.S. Corrugating Medium:

A. Box Performance:

(1) In general, the boxes made with 23-lb. European corrugating medium exhibited equal or slightly lower top- and end-load compression and lower corner drop and drum results than the corresponding boxes made with 26-lb. U.S. corrugating medium.

(2) Reducing the medium weight from 26 to 23 lb. is approximately a 11.5% reduction in medium weight. When box performance was computed on a unit weight basis, the boxes made with 23-lb. European medium generally gave higher top- and end-load compression performance but lower corner drop and drum performance.

(3) In general, the boxes made with U.S. linerboard and 23-lb. and 26-lb. European mediums exhibited slightly higher top-load compression than boxes made with U.S. linerboard and 26-lb. U.S. medium. Boxes in this phase made with 23-lb. European medium gave lower end-load compression and those made with 26-lb. European medium higher end-load compression than boxes made with 26-lb. U.S. medium. The differences noted above for both top-load and end-load were not believed to be significant. Rough handling performance of boxes made with 23-lb. and 26-lb. European mediums was lower than that of boxes made with 26-lb. U.S. medium. There appeared to be no significant difference between the rough handling performance of boxes made with 23-lb. and 26-lb. European mediums.

(4) The 23-lb. European medium was made from a furnish consisting of approximately 85% hardwood (birch) and 15% softwood (mainly Scotch

pine) refined to a substantially lower average fiber length than the 26-lb. U.S. medium which was made from a furnish of approximately 85% hardwood (gum) and 15% softwood (southern pine).

B. Combined Board Performance:

(1) The combined boards fabricated with 26-lb. U.S. corrugating medium were, on the average, 3 to 5% higher in basis weight and higher in flat crush, puncture, torsion tear, machine-direction edgewise compression, and pin adhesion than combined boards made with 23-lb. European corrugating medium. On the other hand, the combined boards made with 26-lb. U.S. corrugating medium were generally slightly lower in bursting strength, cross-machine edgewise compression, and flexural stiffness.

(2) Combined boards made with 26-lb. U.S. corrugating medium generally were higher in torsion tear but slightly lower in flat crush, flexural stiffness, and edgewise compression than combined boards made with 26-lb. European medium. The basis weight, caliper, bursting strength, and puncture results were approximately equal.

C. Corrugating Medium Characteristics:

(1) As would be expected, the actual basis weight of the U.S. corrugating medium was approximately 12% higher than that of the 23-lb. European corrugating medium but about equal to that of the 26-lb. European corrugating medium.

(2) The caliper of the 26-lb. U.S. corrugating medium was approximately 14% higher than the caliper of the 23-lb. European corrugating medium and 6 to 13% higher than the caliper of the 26-lb. European corrugating medium.

(3) The density of the 26-lb. U.S. and 23-lb. European corrugating mediums were equal whereas the density of the 26-lb. European corrugating medium was 4 to 11% higher.

(4) The 26-lb. U.S. corrugating medium exhibited a slightly higher Concora flat crush at 50% R.H. and slightly lower Concora flat crush at 65% R.H. than did the 26-lb. European corrugating medium. Compared with the 23-lb. European medium, the Concora flat crush of the 26-lb. U.S. medium was considerably higher (16 to 18%) at both 50 and 65% R.H.

(5) The water drop test was markedly lower for the U.S. corrugating medium than for the European corrugating medium; this difference may account in part at least for the lower pin adhesion results obtained on boards made with European corrugating mediums.

(6) The 26-lb. U.S. corrugating medium was more porous than the 23-lb. European medium but less porous than the 26-lb. European medium.

(7) The 26-lb. U.S. corrugating medium exhibited higher tearing strength, torsion tear, puncture resistance, and stretch than either the 23- or 26-lb. European corrugating mediums. However, the European mediums were generally higher in ring compression, tensile, and modulus of elasticity than the U.S. 26-lb. corrugating medium. Taber stiffness was lower on the 23-lb. European medium but higher on the 26-lb. European medium when compared with the Taber stiffness on the 26-lb. U.S. corrugating medium.

INTRODUCTION

Throughout the containerboard industry in the free world today, two distinctly different philosophies are practiced relative to containerboard quality. These two philosophies are undoubtedly economically oriented and differ in respect to the importance of weight and bursting strength to box quality. As a result of regulatory end-use requirements in many of the European countries, advantageous wood species and manufacturing economies specific to the Scandinavian countries, Scandinavian unbleached kraft containerboard is characterized by low weight and high bursting strength relative to the corresponding competitive grades of fourdrinier unbleached kraft linerboard made in this country. In certain European countries, notably West Germany, the regulatory requirements specify only bursting strength; thus, the weight of the linerboards is discretionary. In contrast, the regulatory agencies in this country require a specific minimum level of bursting strength at a given minimum weight level. The level of bursting strength in this country is considerably lower than its corresponding European counterpart.

The European philosophy of manufacturing linerboard at a higher bursting strength and lower weight places a burden on U.S. linerboard exportation to those countries where weight is not considered a factor in containerboard quality.

Listed below are the standard basis weights and minimum bursting strength guaranteed by Enso Gutseit, Finland, which became effective January 1, 1961 (1) when they switched from billing on a tonnage basis to a square meter basis together with the corresponding domestic minimum basis weight and bursting strength:

Basis Weight			Bursting Strength		
Scandinavian		U.S.	Scandinavian		U.S.
g./M^2	lb./M sq.ft.	lb./M sq.ft.	kg./sq.cm.	p.s.i.	p.s.i.
125	25.6	26.0	6	85.3	65-75
150	30.7	33.0	8	113.8	75-80
175	35.8	38.0	9	128.0	90-95
200	41.0	42.0	9.4	133.7	105-110
225	46.0	--	9.6	136.5	--
250	51.2	--	9.7	138.0	--
300	61.4	--	9.9	140.8	--

The above standard basis weights and guaranteed bursting strength specifications are also met by the kraft containerboard mills in Norway and Sweden. The Scandinavian specifications are based on 65% R.H. at 68°F. whereas the U.S. equivalents are based on 50% R.H. at 73°F.; thus, the standard basis weight values listed above will be slightly lower at 50% R.H.

U.S. linerboard could be made to the same specifications as Scandinavian linerboards; however, this would require modifying current manufacturing practices which, coupled with less advantageous wood species, would adversely influence costs. Moreover, it has not been demonstrated that boxes fabricated with Scandinavian linerboards, manufactured in keeping with the high Mullen philosophy, necessarily perform better than boxes fabricated with domestic linerboards manufactured according to current practice and specifications.

As a result of the foregoing it appeared worthwhile and timely for the Fourdrinier Kraft Board Institute to study the comparative performance of combined boards and boxes made with components manufactured according to the two aforementioned philosophies.

Phase I of the Comparative Performance Study was initiated at The Institute of Paper Chemistry on behalf of the Fourdrinier Kraft Board Institute, Inc., for the purpose of evaluating the comparative performance of combined board and boxes made from both European and domestic components, manufactured according to their traditional specifications, and fabricated by a United States converter. The Comparative Performance Study as initially outlined involves two phases - Phase I, as described above; and Phase II, which is concerned with the fabrication and evaluation in Europe of combined board and boxes made from the same lot of component materials. This design or arrangement permits Phase I to be undertaken and, which, if successful, could then proceed logically into Phase II.

The scope of Phase I relative to material combinations is shown in Fig. 1. This represents a significant enlargement of the scope as originally proposed. It may be noted that Phase I involves the fabrication of four weights of domestic linerboard - 26, 33, 38, and 42-lb. - and four competitive weights - 25.6, 30.7, 35.8, and 41.0-lb. - of European liners, from each of two manufacturers, with both 26-lb. domestic and 23-lb. European semichemical corrugating medium into A- and B-flute combined board and boxes. In addition, the four domestic linerboard samples were fabricated with a sample of European 26-lb. semichemical medium into A-flute combined board and boxes.

Run No.	Nominal Grade Liner Weight	Nominal Grade	Medium Weight
1	25.6-lb. Enso Gutseit		
2	26.0-lb. U. S.		
3	25.6-lb. Svenska Cellulosa		
4	30.7-lb. " "		
5	33.0-lb. U. S.		
6	30.7-lb. Enso Gutseit		
7	35.8-lb. " "	26-lb. U. S.	A and B Flute
8	38.0-lb. U. S.		
9	35.8-lb. Svenska Cellulosa		
10	41.0-lb. " "		
11	42.0-lb. U. S.		
12	41.0-lb. Enso Gutseit		
13	25.6-lb. Enso Gutseit		
14	26.0-lb. U. S.		
15	25.6-lb. Svenska Cellulosa		
16	30.7-lb. " "		
17	33.0-lb. U. S.		
18	30.7-lb. Enso Gutseit		
19	35.8-lb. " "	23-lb. European	A and B Flute
20	38.0-lb. U. S.		
21	35.8-lb. Svenska Cellulosa		
22	41.0-lb. " "		
23	42.0-lb. U. S.		
24	41.0-lb. Enso Gutseit		
25	26.0-lb. U. S.		
26	33.0-lb. " "		
27	38.0-lb. " "	26-lb. European	A Flute
28	42.0-lb. " "		

Figure 1. Phase I — Material Combinations

FABRICATION AND EVALUATION

The fabrication was carried out on one corrugator, Menasha Corporation, Menasha, Wisconsin, and the same conditions were used where possible. Starch was used as the adhesive and the combined boards were made into boxes (RSC) size 11-3/4 by 8-3/16 by 9-3/4 inches. A portion of the boxes of each sample was stitched and the balance was taped. This size box corresponds to a No. 24, 12-oz. juice container. The size was selected so as to comply with the carrier specifications both here and abroad for boxes made with 25.6 and 26.0-lb. liners.

The domestic linerboard and corrugating medium manufacturing specifications were selected so as to be representative of the general or average quality of board currently produced in these particular grade weights. These specifications were as follows:

Linerboard Specifications[a]

	Nominal Linerboard Grade Weight Levels			
	26-lb.	33-lb.	38-lb.	42-lb.
Test property				
Bursting strength, p.s.i.g.	75	95	103	110
Bursting strength, factor	2.9	2.9	2.7	2.6
Modified ring compression				
M.D., lb./in.	13.0	16.5	19.0	20.6
M.D., factor	0.50	0.50	0.50	0.49
C.D., lb./in.	10.7	13.2	15.2	16.8
C.D., factor	0.41	0.40	0.40	0.40
Tearing strength				
M.D., g./sheet	182	238	285	323
M.D., factor	7.0	7.2	7.5	7.7
C.D., g./sheet	198	267	315	378
C.D., factor	7.6	8.1	8.3	9.0

[a]Conditioned at 50% R.H., 73°F.

Corrugating Medium Specification[a]

Weight, lb /M sq ft	26.0
Modified ring compression	
C.D , lb./in.	12.4
C.D., factor	0 48
Concora flat crush, p s i.	38.0
Concora flat crush, factor	1 46

[a]Conditioned at 50% R.H., 73°F.

As previously mentioned, two sets of European linerboards were selected These were Enso Gutseit (E.G.) of Finland and Svenska Cellulosa (S.C.) of Sweden The 23- and 26-lb semichemical corrugating mediums came from Fiskeby and Finnkarton, respectively In order to maintain as great a degree of anonymity as possible, the European components were obtained via an European affiliate of Container Corporation of America through the efforts of Mr Spachner The materials were ordered by and delivered to the affiliate company which in turn reshipped the materials. A sufficient quantity of materials, both domestic and foreign, were obtained to carry out Phase II, if it is deemed advisable The domestic components are currently in storage at Appleton, Wisconsin, and the European components in Hamburg, Germany.

The boxes, combined boards and components resulting from the fifty-two different material combinations described in Fig. 1 were evaluated at two atmospheric conditions, one representing standard conditions in this country (50% relative humidity at 73°F.) and the other representing standard conditions in Europe (65% relative humidity at 68°F.).

Prior to evaluation, each box, combined board and component sample was randomized and preconditioned for 24 hours in an atmosphere maintained at 35%

relative humidity at 73°F. After the prescribed preconditioning, each sample was conditioned in the respective standard conditions for at least 48 hours and then tested in the same atmosphere.

The experimental box samples were evaluated for the two general classifications of box performance – namely, resistance to compression and rough handling. Compression resistance was determined by means of top- and end-load compression tests. After preconditioning as described the boxes were conditioned in the selected standard atmosphere for 24 hours, and then the boxes were sealed. After sealing, the boxes were allowed to condition for an additional 48 hours prior to testing.

The rough handling resistance of the fifty-two box samples was evaluated by means of the drop test (12-inch corner drop) and the drum test (7-foot revolving drum). Only the boxes made with a stitched manufacturers joint were used for the rough handling tests. After preconditioning, each box specimen was conditioned for 24 hours in the selected standard atmosphere and then the bottoms were sealed and the box loaded with twenty-four 12-oz. juice cans filled (one inch from top) with water. The weight of the twenty-four filled cans was 19.65 pounds, thus, the gross weight of the test specimen was just over 20 pounds. After filling with cans, top closure was made by sealing and the thus assembled test specimen was allowed to condition for an additional 48 hours in the selected standard atmosphere and then tested.

The combined board test specimens were all cut from the knock-down boxes. The combined board tests run and the procedures used are listed below.

	Test	Method	Number of Tests
1.	Basis weight	T 410	1000 sq. in.
2.	Caliper	IPC 904	10
3.	Bursting strength	IPC 906	10 (5 up; 5 down)
4.	Puncture	T 803	10 (5 each way)
5.	Torsion tear	IPC 913	10 in; 10 cross; flap score
6.	Column compression	IPC 919	10 each way
7.	Flexural stiffness	IPC 920	10 each way
8.	Flat crush	IPC 911	10 each way
9.	Pin adhesion	IPC 914	6 (3 up; 3 down)

During the fabrication of the fifty-two different material combinations, sample strips the full width of each component roll were taken at the start and end of each material combination. The start and end samples of each component for each material combination were tested separately and the test results averaged to give a characterization of the quality of the components used in each material combination. The properties of the components measured at each of the two atmospheric conditions are given as follows, together with the procedures used:

1.	Basis weight	T 410	1000 sq. in.
2.	Caliper	T 411	10
3.	Apparent density	T 411	--
4.	Bursting strength	IPC 906	10 (5 up; 5 down)
5.	Elmendorf tearing strength	T 414	10 each way
6.	Torsion tear	IPC 913	10 each way
7.	Puncture	T 803	10 (5 each way)
8.	Modified ring	IPC 918	10 each way
9.	Taber stiffness	T 489	10 each way
10.	Tensile	T 404	10 each way
11.	Stretch		10 each way
12.	Modulus of elasticity	--	10 each way
13.	Tensile energy absorption or work	--	10 each way
14.	Transverse bond strength	--	5 each way
15.	Porosity	T 460	5
16.	Smoothness (Bendsten smoothness)	--	5 (felt side)
17.	Cobb size	T 441	5

Further, for the purpose of obtaining a rough comparison of the type of furnish and the degree of refining, each component material was subjected to fiber analysis, specie identification, and fiber length In addition, Canadian freeness determinations were made on a sample of each component. The freeness determinations were made as follows

The sample of component (liner or medium) was conditioned at 50% relative humidity to constant weight. A total of 26 grams of fiber was weighed out and torn into small pieces (approximately one inch square). The thus prepared board material was then soaked in 500 cc of water at room temperature for 4 hours At the end of the 4 hours, the water-soaked material was transferred to the British disintegrator and water added to give a total mass of 2000 grams. The stock was disintegrated for 75,000 revolutions and then diluted to 6000 cc The consistency of the slurry was determined and a volume equivalent to 3 grams of fiber was removed, diluted to 1000 cc., and the Canadian standard freeness determined The classification of the components as to specie, fiber content, fiber length, and freeness of defibered board is given in Table I.

TABLE I

FIBER CHARACTERISTICS OF LINERBOARD AND MEDIUM SAMPLES

Sample	Fiber Analysis		Specie	Av Fiber Length,[a] mm	C S. Freeness,[b] cc
U S. 26-lb. liner	S W. unbleached kraft H.W. unbleached kraft	85% 15%	Southern pine Gum	2 51	595
U.S. 33-lb liner	S W. unbleached kraft H.W. unbleached kraft	95% 5%	Southern pine Mainly gum, but trace of oak, beech, maple and yellow poplar	2 41	585
U.S. 38-lb. liner	-- --	--	-- --	--	625
U.S 40-lb. liner	S.W unbleached kraft H W. unbleached kraft	85% 15%	Southern pine Gum	2 52	565
E G. 25.6 liner	S.W. unbleached kraft H.W. kraft	100% trace	Scotch pine 90% Norway spruce 10% Birch	2.19	560
E.G. 30 7-lb liner	S.W. unbleached kraft H.W. kraft	100% trace	Scotch pine 90% Norway spruce 10% Birch	2.23	530
E.G 35.8-lb. liner	S.W. unbleached kraft H.W. kraft	100% trace	Scotch pine 90% Norway spruce 10% Birch	2 20	560
E.G. 41.0-lb. liner	S.W unbleached kraft H.W. kraft	100% trace	Scotch pine 90% Norway spruce 10% Birch	2 18	595

Footnotes are given at end of Table I, page 31

... LINERBOARD AND MEDIUM SAMPLES

Sample			Fiber Analysis		Specie	Av[a] Fiber Length, mm.	C S Freeness,[b] cc
S C.	25 6-lb	liner	S W unbleached kraft	100%	Scotch pine 90% Norway spruce 10%	2.22	510
			H.W. kraft	trace	Birch		
S.C	30 7-lb.	liner	S.W. unbleached kraft	100%	Scotch pine 90% Norway spruce 10%	2.32	570
			H.W. kraft	trace	Birch		
S.C	35 8-lb	liner	S.W. unbleached kraft	100%	Scotch pine 90% Norway spruce 10%	2 20	560
			H W. kraft	trace	Birch		
S C	41.0-lb	liner	S.W unbleached kraft	100%	Scotch pine 90% Norway spruce 10%	2 27	530
			H.W. kraft	trace	Birch		
U S	26-lb	medium	S.W unbleached kraft H W. unbleached NSSC	15% 85%	Southern pine Gum	1 40	455
Eur	25-lb	medium	S.W. unbleached kraft	15%	Scotch pine 90% Norway spruce 10%	1 24	485
			H W unbleached NSSC	85%	Birch		
Eur	26-lb	medium	--	--	--	1 37	600

[a] Weighted average fiber length.
[b] Determined on defibered board

PRESENTATION AND DISCUSSION OF RESULTS

I. LINERBOARD RESULTS

A Background

As previously mentioned, two markedly different "quality" philosophies are active in the container industry today Scandinavian containerboard, which is one of Europe's main sources of virgin component material, is manufactured to higher bursting strength and lower weight levels than the corresponding competitive grade weights in this country. Because of practice and custom associated with shorter hauls, less emphasis on compression, etc., approximately 90% of European needs for linerboard are satisfied by three grade weights – 25.6 (125 g./sq m.), 30 7 (150 g /sq.m), and 35.8 lb./1000 sq. ft. (175 g./sq m.) (2). A small percentage of 41.0 lb. (200 g./sq.m) linerboard is produced, however, the main competition is in the lower three weights

Because adoption of European practice and specification in the manufacture of U.S. linerboard for export to Europe would significantly increase cost, and equally important, because numerous studies (3-5) have shown that bursting strength by itself is a poor criterion of quality, a study of the comparative performance of combined board and boxes made with both European and domestic components was undertaken As previously described, the main study involved the fabrication of four grade weights of linerboard from two European sources (Enso Gutseit and Svenska Cellulosa) and one domestic source with 23-lb (112 g /sq m) Scandinavian semichemical and 26-lb. domestic semichemical corrugating medium into A- and B-flute combined board and boxes.

It should be borne in mind in interpreting the results of this study that the data are based on only one sample of domestic and two samples of

European linerboard at each grade weight. Therefore, the comparisons of performance are valid only to the extent that the three linerboard samples at each grade weight level are representative of the quality levels being maintained by the U.S. and European industries.

Before comparing the combined board and box performance it may be helpful to consider the disparity in weight and bursting strength of the European and domestic linerboards. The respective results are tabulated in Table II.

TABLE II

COMPARISON OF LINERBOARD WEIGHT AND BURSTING STRENGTH
at 50% R.H.

Grade	U.S.	E.G.	Diff., %[a]	S.C.	Diff., %[a]
			Basis Weight		
Nominal grade	26.0	25.6	-1.5	25.6	-1.5
Observed grade	28.0	26.5	-5.4	26.7	-4.6
Nominal grade	33.0	30.7	-7.0	30.7	-7.0
Observed grade	35.0	31.8	-9.1	31.0	-11.4
Nominal grade	38.0	35.8	-5.8	35.8	-5.8
Observed grade	39.4	37.4	-5.1	36.4	-7.6
Nominal grade	42.0	41.0	-2.4	41.0	-2.4
Observed grade	42.8	41.6	-2.8	39.6	-7.5
			Bursting Strength		
25.6 - 26.0-lb.	72	100	+38.9	106	+47.2
30.7 - 33.0-lb.	105	124	+18.1	112	+6.7
31.8 - 38.0-lb.	98	136	+38.8	136	+38.8
41.6 - 42.0-lb.	115	146	+27.0	137	+19.1

[a] Based on U.S. as reference.

A number of conditions are evident from the data tabulated in Table [illegible]. It may be observed that on the basis of nominal grade weights the greatest disparity between the domestic and European linerboards is at the two middle grade weight levels - i.e., 30.7, 33.0-lb. and 35.8, 38.0-lb. The least disparity is at the lowest grade weight level. In all but one case, the actual or observed linerboard weight exceeded the corresponding nominal grade weight. The degree to which the nominal grade weight was exceeded is in general greatest for the domestic linerboards. The observed differences in linerboard weight between the domestic and European samples are in most cases greater than the differences in the nominal linerboard weights. In general, the linerboards from Svenska Cellulosa are lower in weight than the corresponding grade weight from Enso Gutseit. It may be further observed that even though the European linerboards are lower in weight they are considerably higher in bursting strength than the domestic linerboard.

With the above as background, it may be appropriate now to consider the results obtained on the combined board and boxes fabricated with domestic and European linerboards. It may be recalled that the program involved the fabrication of one domestic and two European linerboards at each of four "Competitive" linerboard grade weight levels. At each level, each linerboard was fabricated with 26-lb. domestic and 23-lb. European semichemical medium into A- and B-flute boxes. Thus, at each weight level each linerboard was used in the fabrication of four combined boards varying only in type of medium or flute. Because of the limited number of linerboard samples and the fact that each linerboard sample was involved in the same four material or structural combinations at each grade weight level, the data have been assembled on the following basis for the purpose of showing the comparative performance:

1. Linerboards fabricated with 26-lb. domestic medium into A-flute combined board and boxes.
2. Linerboards fabricated with 26-lb. domestic medium into B-flute combined board and boxes.
3. Linerboards fabricated with 23-lb. European medium into A-flute combined board and boxes.
4. Linerboard fabricated with 23-lb. European medium into B-flute combined board and boxes.
5. Composite averages of A- and B-flute combined board and boxes.

B. Comparative Performance of Boxes Fabricated with U.S. and European Linerboards

1. Compression Performance

The box compression results obtained at 50 and 65% R.H. are tabulated in Tables III and IV, respectively, and illustrated in Fig. 2a. The results tabulated in Tables III and IV have been analyzed statistically (see Appendix for procedure) for the purpose of determining whether the differences in composite averages are significant at the 1 and 5% levels and also for the purpose of determining the 5% confidence limits shown in Fig. 2 at each level of linerboard weight.

When the top-load box compression results are considered it may be observed from the data in Tables III and IV and Fig. 2a that the 25.6-26.0-lb. linerboard grade weight level, the boxes made with U.S. linerboard exhibit higher average box compression at 50 and 65% R.H. than do the boxes made with Enso Gutzeit or Svenska Cellulosa linerboards. The top-load compression results of the boxes made with U.S. linerboard and tested at 50% R.H. are approximately 5% higher than the corresponding results for the boxes made with European

TABLE III

BOX COMPRESSION PERFORMANCE

(50% Relative Humidity)

Run	Plate	Type Medium	Top-Load (0-0.75 in.), lb U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	End-Load (0-0.5 in.), lb U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]
			25.6, 26.0-lb Linerboards									
[illegible] 6	A	25-lb U.S.	530	510	- 3.8	520	- 1.9	270	245	- 9.3	255	- 5.6
[illegible]	B	26-lb U.S.	460	445	- 3.3	440	- 4.3	330	340	+ 3.0	345	+ 4.5
[illegible]	A	23-lb European	565	520	- 8.0	530	- 6.2	255	230	- 9.8	255	0.0
[illegible]	B	23-lb European	465	435	- 6.5	435	- 6.5	330	320	- 3.0	320	- 3.0
Average			505	478	- 5.3(.01)[b]	481	- 5.1(.01)	296	284	- 4.1(N.S.)	294	- 0.7(N.S.)
			30.7, 33.0-lb Linerboards									
[illegible], 11	A	26-lb U.S.	595	615	+ 3.4	610	+ 2.5	345	350	+ 1.4	340	- 1.[illegible]
[illegible], 11	B	26-lb U.S.	545	545	0.0	525	- 3.7	480	410	-14.6	440	- 8.3
[illegible] 12	A	23-lb European	590	595	+ 0.8	625	+ 5.9	350	335	- 4.3	355	+ [illegible]
[illegible] 12	B	23-lb European	545	555	+ 1.8	515	- 5.5	420	415	- 1.2	415	- 1.2
Average			569	578	+ 1.6(.01)	569	0.0(N.S.)	399	378	- 5.3(.01)	388	- 2.8(N.S.)
			35.8, 38.0-lb Linerboards									
[illegible] 14, 18	A	26-lb U.S.	535	690	+ 8.7	540	+ 0.8	400	405	+ 1.2	385	- 3.8
[illegible] 14, 18	B	26-lb U.S.	565	600	+ 6.2	590	+ 4.4	535	520	- 2.8	435	-18.7
[illegible] 13, [illegible]	A	23-lb European	660	675	+ 2.3	630	- 4.5	[illegible]	415	+ 3.9	390	- 2.5
[illegible] 13, [illegible]	B	23-lb European	560	635	+13.4	585	+ 4.5	460	495	+ 7.6	425	- 7.6
Average			605	650	+ 7.4(.01)	611	+ 1.0(N.S.)	449	459	+ 2.2(N.S.)	409	- 8.9(.01)
			41, 42-lb. Linerboards									
23, 19, 22	A	26-lb U.S.	730	775	+ 6.2	715	- 2.1	455	470	+ 3.3	495	+ 8.8
23, 19, 22	B	26-lb U.S.	600	640	+ 6.7	640	+ 6.7	590	610	+ 3.4	535	- 9.3
24, 20, 21	A	23-lb European	725	815	+12.4	740	+ 2.1	440	485	+10.2	490	+11.4
24, 20, 21	B	23-lb European	575	630	+ 5.7	650	+13.0	535	600	+12.1	575	- 7.5
Average			658	715	+ 8.7(.01)	686	+ 2.7(.01)	505	541	+ 7.1(.01)	524	+ 3.8(N.S.)

---

[a] Based on U.S. liner results as reference.

[b] Value in parenthesis indicates significance level; (N.S.) means difference is not significant at [illegible] level [illegible] or 5% level.

TABLE IV

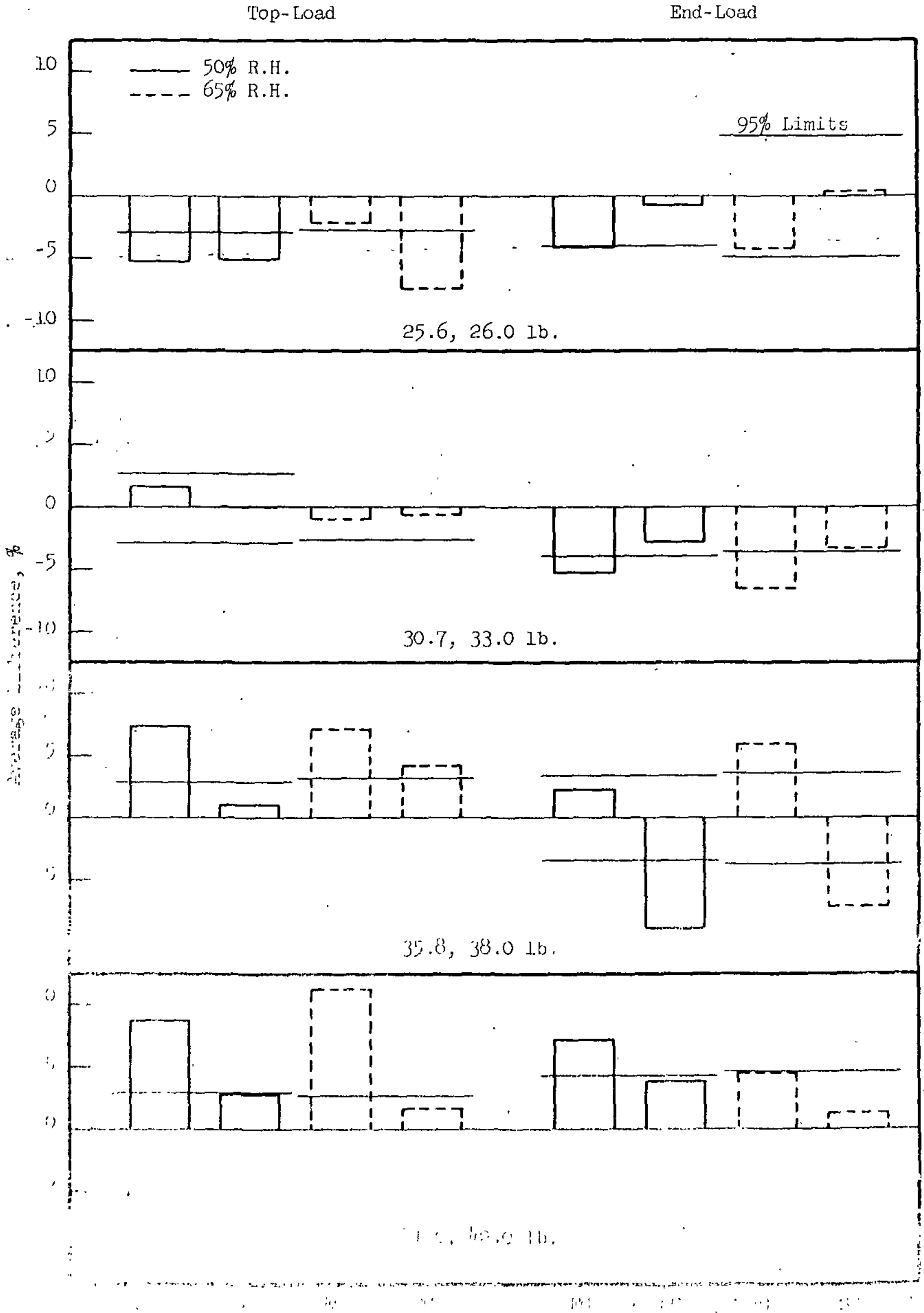
BOX COMPRESSION PERFORMANCE

(65% Relative Humidity)

Run	Flute	Type Medium	Top-Load (0-0.75 in.), lb. U.S. Liner	Top-Load E.G. Liner	Top-Load Diff., % [a]	Top-Load S.C. Liner	Top-Load Diff., % [a]	End-Load (0-0.5 in.), lb. U.S. Liner	End-Load E.G. Liner	End-Load Diff., % [a]	End-Load S.C. Liner	End-Load Diff., % [a]
25.6, 26.0-lb. Linerboard												
3, 2, 6	A	26-lb. U. S.	490	465	- 5.1	470	- 4.1	235	210	-10.6	235	0.0
3, 2, 6	B	26-lb. U. S.	405	425	+ 4.9	405	0.0	310	305	- 1.6	305	- 1.6
4, 1, 5	A	23-lb. European	520	515	- 1.0	455	-12.5	225	220	- 2.2	220	- 2.2
4, 1, 5	B	23-lb. European	450	420	- 6.7	395	-12.2	290	280	- 3.4	305	+ 5.2
Average			466	456	- 2.1(N.S.)[b]	431	- 7.5(.01)	265	254	- 4.2(N.S.)	266	+ 0.4(N.S.)
30.7, 33.0-lb. Linerboard												
10, 7, 11	A	26-lb. U. S.	560	540	- 3.6	545	- 2.7	330	305	- 7.6	305	- 7.6
10, 7, 11	B	26-lb. U. S.	495	510	+ 3.0	495	0.0	420	355	-15.5	415	- 1.2
9, 8, 12	A	23-lb. European	540	545	+ 0.9	575	+ 6.5	305	305	0.0	335	+ 9.8
9, 8, 12	B	23-lb. European	500	480	- 4.0	470	- 6.0	395	385	- 2.5	380	- 3.8
Average			524	519	- 1.0(N.S.)	521	- 0.6(N.S.)	362	338	- 6.6(.01)	359	- 0.8(N.S.)
35.8, 38.0-lb. Linerboard												
15, 14, 18	A	26-lb. U. S.	600	605	+ 0.8	625	+ 4.2	360	370	+ 2.8	340	- 5.6
15, 14, 18	B	26-lb. U. S.	535	570	+ 6.5	570	+ 6.5	480	485	+ 1.0	455	- 5.2
16, 13, 17	A	23-lb. European	600	610	+ 1.7	615	+ 2.5	345	400	+15.9	350	+ 1.4
16, 13, 17	B	23-lb. European	510	620	+21.6	525	+ 2.9	445	475	+ 6.7	370	-16.9
Average			561	601	+ 7.1(.01)	584	+ 4.1(.01)	408	432	+ 5.9(.01)	379	- 7.1(.01)
41, 42-lb. Linerboard												
23, 19, 22	A	26-lb. U. S.	670	750	+11.9	685	+ 2.2	420	440	+ 4.8	430	+ 2.4
23, 19, 22	B	26-lb. U. S.	570	620	+ 8.8	580	+ 1.8	540	555	+ 2.8	555	+ 2.8
24, 20, 21	A	23-lb. European	675	735	+ 8.9	625	- 7.4	410	470	+14.6	430	+ 4.9
24, 20, 21	B	23-lb. European	515	600	+16.5	580	+12.6	550	540	- 1.8	530	- 3.6
Average			608	676	+11.2(.01)	618	+ 1.6(N.S.)	480	501	+ 4.4(N.S.)	486	+ 1.2(N.S.)
Over-all average			540	563	+ 4.3	538	- 0.4	379	381	+ 0.5	372	- 1.8

[a] Based on U. S. liner results as reference.

[b] Value in parenthesis indicates significance level: (.01) means difference is significant at 1% level; (.05) significant at 5% level; (N.S.) difference not statistically significant at 1 or 5% level.


Top-Load
End-Load
50% R.H.
65% R.H.
95% Limits
25.6, 26.0 lb.
30.7, 33.0 lb.
35.8, 38.0 lb.
10
5
0
-5
-10

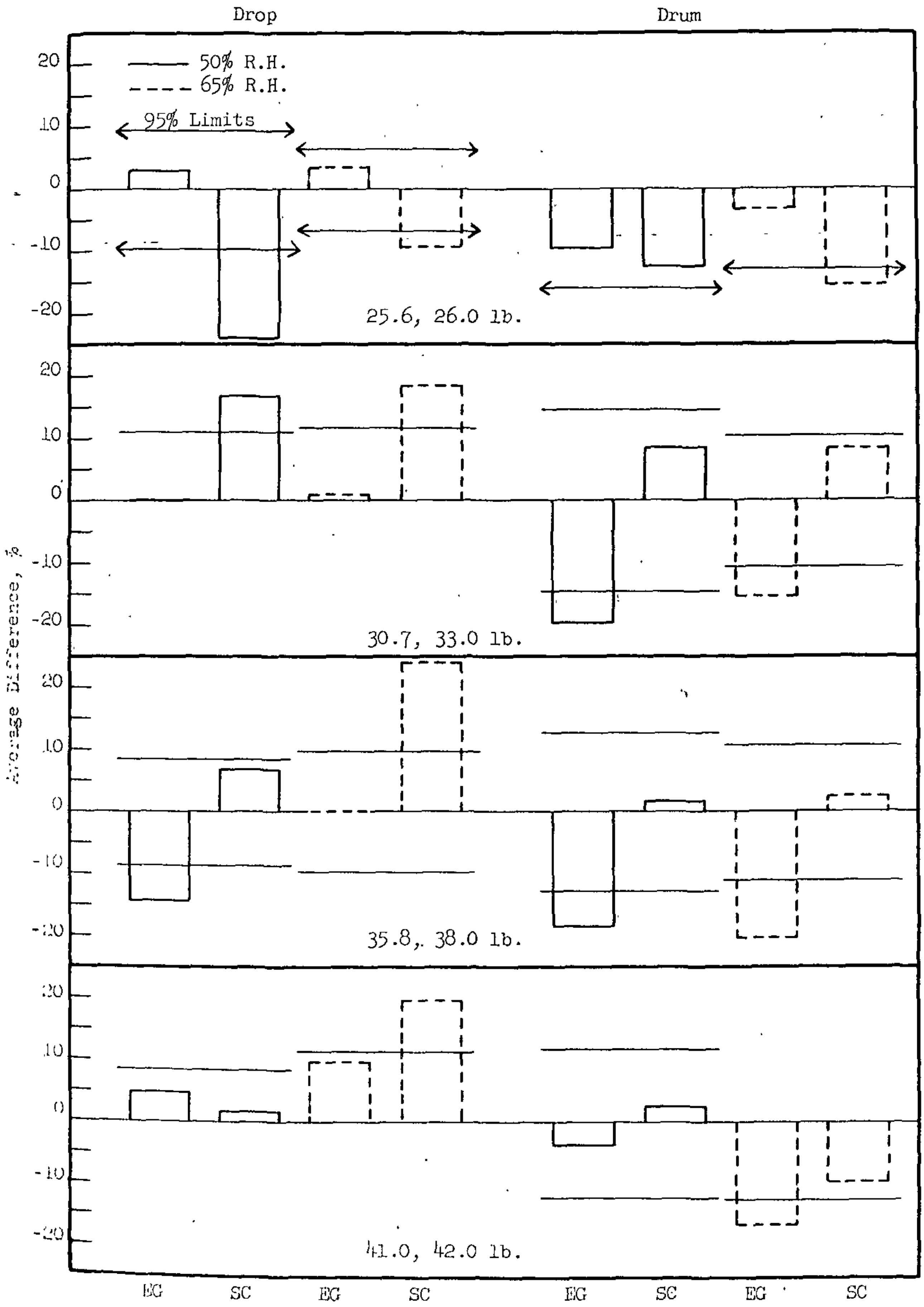


Figure 2b. Comparison of Average Difference in Rough Handling

linerboards, the differences are statistically significant at the 1% level In other words, differences such as shown for composite averages could occur by chance only one out of a hundred times At 65% R.H. the composite average differences were 2.1 and 7.5%, respectively, for the boxes made with Enso Gutseit and Svenska Cellulosa linerboards. The difference between the results for the boxes made with U.S and Enso Gutseit linerboards is not significant whereas the corresponding difference for the Svenska Cellulosa linerboard is significant

At the 30 7 - 33.0-lb. linerboard grade weight level, the composite average top-load compression results differ by 1.6% or less at 50 and 65% R H These differences are in general too small to be termed significant, thus, the conclusion is drawn that at this level there is no significant difference in box compression due to type of linerboard.

When the results at the 35.8 - 38.0-lb. linerboard grade weight level are considered, it may be seen that the boxes made with Enso Gutseit linerboard exhibit top-load compression results at 50 and 65% R H. which were 7 4 and 7 1% higher, respectively, than the boxes made with U.S. linerboard These differences are found to be large enough to represent significant differences at the 1% level. The corresponding results for the boxes made with Svenska Cellulosa are also higher (1.0 and 4.1%) than the results for the boxes made with U S. linerboard — the 1 0% difference is not significant at the 5% level whereas the 4.1% difference is significant at the 1% level.

At the 41.0 - 42 0-lb linerboard grade weight level the boxes made with European linerboards exhibit higher top-load compression results than the corresponding boxes made with U.S. linerboard The results at 50 and 65% R.H are, respectively, 8 7 and 11.2% higher for the boxes made with Enso Gutseit linerboard and 2.7 and 1.6% higher for the boxes made with Svenska Cellulosa linerboard than the corresponding boxes made with U.S linerboard The differences observed for the boxes made with Enso Gutseit linerboard are found to be significant at the 1% level The difference (2.7%) noted for the boxes made with Svenska Cellulosa linerboard at 50% R.H. is significant whereas the difference (1.6%) at 65% R.H. is not significant.

On the basis of the compression results obtained on the boxes fabricated in this study, it appears that at the lowest linerboard grade weight the boxes made with U.S. linerboard exhibit higher top-load compression than the boxes made with slightly lighter weight but higher bursting strength European linerboards At the 30.7 - 33.0-lb linerboard grade weight level the top-load compression is the same for the boxes made with U.S. and European linerboards — that is, there is, in general, no significant difference in the results At the 35.7, 38.0-lb and 41.0, 42.0-lb. linerboard grade weight levels, the boxes made with Enso Gutseit linerboard exhibit significantly higher compression results than the corresponding boxes made with U.S. linerboard. When the results for boxes made with U S. and Svenska Cellulosa linerboards are compared, it may be seen that, in general, the U S. box results were either only slightly lower or equal on the basis of composite averages.

It was pointed out earlier that one of the characteristic differences between domestic and European fourdrinier kraft linerboard is the bursting strength-weight ratio European (Scandinavian) linerboard is manufactured at a nominal grade weight 1 5-7.0% lower than the corresponding U.S. linerboard but at a substantially higher bursting strength (10-35%) The European practice of running to a lower weight places U S containerboard in a difficult position in the export market because of the difference in square footage per ton Accordingly, in order to compare the performance on an equal weight basis the results tabulated in Tables III and IV have been converted to a unit weight basis by dividing the box compression results by their corresponding combined board weigh multiplied by 100. Thus, the calculated compression results are expressed as the pounds of box compression per 100 pounds of combined board weight. The results on the unit weight basis are presented in Tables V and VI and graphically illustrated in Fig. 3a. When the top-load box compression results at the 25.6, 26.0- level are expressed on a unit combined board weight basis, it may be seen that the boxes made with U.S. linerboard generally exhibit slightly higher top-load compression results than the corresponding boxes made with European linerboards; however, it is doubtful that the differences noted are significant. In other words, at this level of linerboard weight it appears that the top-load box compression per unit of combined board weight is not significantly different. Thus the advantage noted earlier on a box basis is erased when compared on a unit weight basis.

On a unit weight basis, the compression results obtained on the boxes made with U.S. linerboards are lower at the three other grade weights than the boxes made with European linerboards. On the basis of composite average differences the results a[illegible]

Grade-Wei[illegible]	Av. Difference Composite Avs., % 50% R.H. E.G.	S.C.	65% R.H. E.G.	S.C.
30.7,	+7.5	+6.8	+4.5	+6.9
35.8,	+11.1	+5.5	+12.9	+9.5
41.0,	+11.3	+9.6	+13.1	+6.3

In all cases, it ap[illegible] the differences are significant. In general, at these three weight levels [illegible] boxes made with U.S. linerboards ranged from approximate 4.5 - 13.1% lower [illegible] boxes made with Enso Gutseit linerboards and approximately 5.5 - 9.6% [illegible] boxes made with Svenska Cellulosa linerboards.

TABLE V

COMPARISON OF COMPRESSION PERFORMANCE PER UNIT WEIGHT OF COMBINED BOARD
(50% Relative Humidity)

			Top-Load Compression, lb./100-lb. Combined Board Weight					End-Load Compression, lb./100-lb. Combined Board Weight				
Run	Flute	Type Medium	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]
			25.6, 26.0-lb. Linerboard									
3, 2, 6	A	26-lb. U.S.	520	515	- 1.0	536	+ 3.1	265	247	- 6.8	263	- 0.8
3, 2, 6	B	26-lb. U.S.	489	473	- 3.3	469	- 4.1	351	362	+ 3.1	367	+ 4.6
4. 1, 5	A	23-lb. European	583	553	- 5.1	570	- 2.2	263	245	- 6.8	274	+ 4.2
4, 1, 5	B	23-lb. European	511	489	- 4.3	489	- 4.3	363	360	- 0.8	359	- 1.1
Average			526	509	- 3.2	517	- 1.7	308	302	- 1.9	316	+ 1.9
			30.7, 33.0-lb. Linerboard									
10, 7, 11	A	26-lb. U.S.	522	569	+ 9.0	570	+ 9.2	303	324	+ 6.9	318	+ 5.0
10, 7, 11	B	26-lb. U.S.	491	519	+ 5.7	505	+ 2.9	432	390	- 9.7	423	- 2.1
9, 8, 12	A	23-lb. European	542	572	+ 5.5	607	+12.0	321	322	+ 0.3	345	+ 7.5
9, 8, 12	B	23-lb. European	514	555	+ 8.0	526	+ 2.3	396	415	+ 5.3	423	+ 6.8
Average			517	556	+ 7.5	552	+ 6.8	362	363	+ 0.3	377	+ 4.1
			35.8, 38.0-lb. Linerboard									
15, 14, 18	A	26-lb. U.S.	516	580	+12.0	542	+ 5.0	325	340	+ 4.6	326	+ 0.3
15, 14, 18	B	26-lb. U.S.	475	526	+10.7	518	+ 9.1	450	456	+ 1.3	382	-15.1
16, 13, 17	A	23-lb. European	559	592	+ 5.9	558	- 0.2	339	364	+ 7.4	345	+ 1.8
16, 13, 17	B	23-lb. European	496	583	+17.5	547	+10.3	407	454	+11.5	397	- 2.5
Average			513	570	+11.1	541	+ 5.5	381	403	+ 5.8	362	- 5.0
			41.0, 42.0-lb. Linerboard									
23, 19, 22	A	26-lb. U.S.	562	605	+ 7.7	577	+ 2.7	350	367	+ 4.9	399	+14.0
23, 19, 22	B	26-lb. U.S.	476	525	+10.3	542	+13.9	468	500	+ 6.8	453	- 3.2
24, 20, 21	A	23-lb. European	575	663	+15.3	617	+ 7.3	349	394	+12.9	408	+16.9
24, 20, 21	B	23-lb. European	479	529	+10.4	560	+16.9	446	504	+13.0	496	+11.2
Average			522	581	+11.3	572	+ 9.6	401	440	+ 9.7	437	+ 9.0

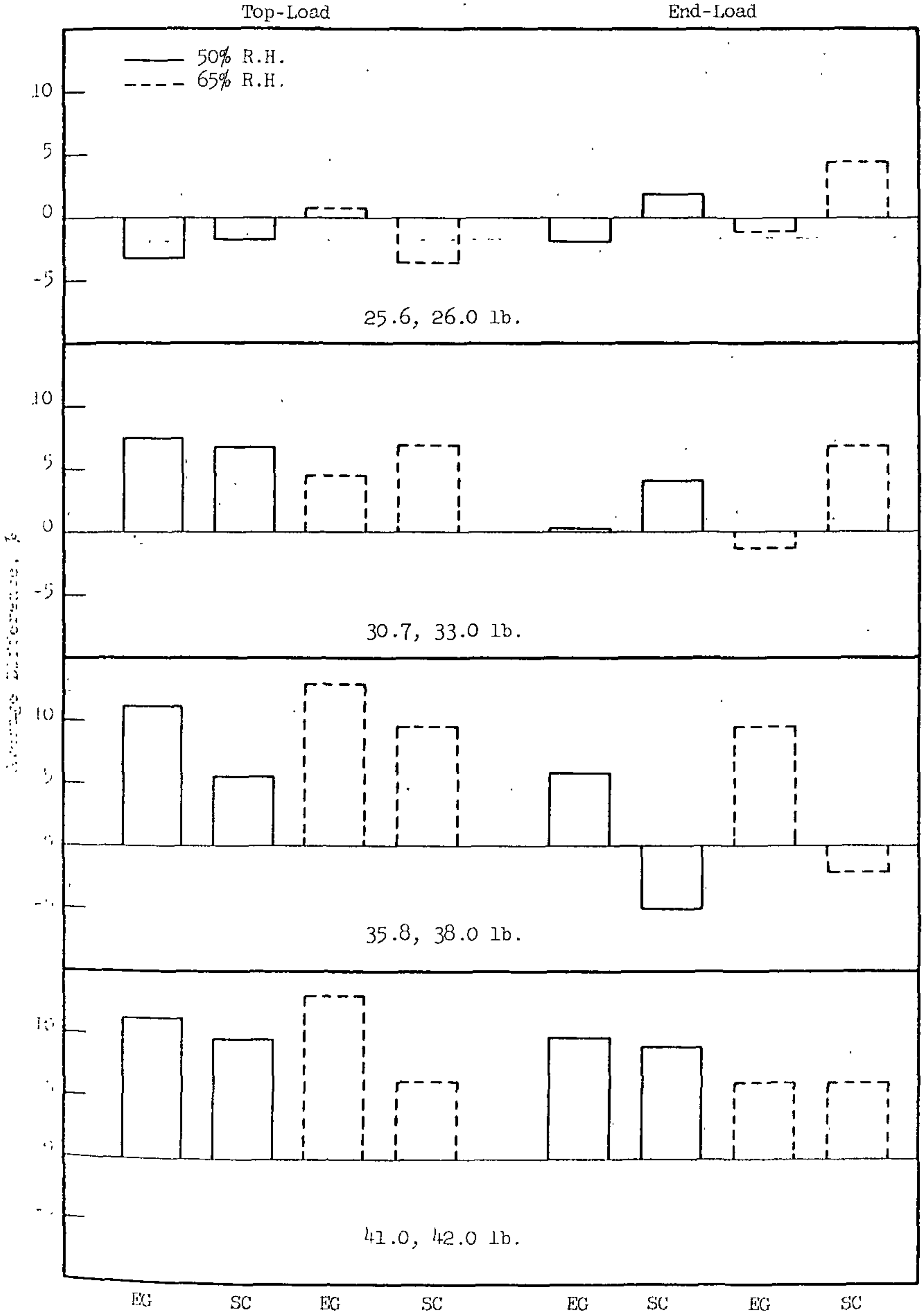
[a] See Note Table III.

TABLE VI

COMPARISON OF COMPRESSION PERFORMANCE PER UNIT WEIGHT OF COMBINED BOARD
(65% Relative Humidity)

Run	Flute	Type Medium	Top-Load Compression, lb /100-lb Combined Board Weight: U S. Liner	E.G. Liner	Diff.,[a] %	S.C. Liner	Diff.,[a] %	End-Load Compression, lb /100-lb Combined Board Weight: U.S Liner	E G. Liner	Diff ,[a] %	S.C Liner	Diff.,[a] %
			25 6, 26.0-lb. Linerboard									
3, 2, 6	A	26-lb. U S.	471	460	- 1.2	475	+ 0 8	226	208	- 8 0	237	+ 4 0
3, 2, 6	B	26-lb. U S	413	443	+ 7 3	422	+ 2.2	316	318	+ 0 6	318	+ 0 6
4, 1, 5	A	23-lb. European	525	536	+ 2.1	479	- 8.8	227	229	+ 0.9	232	+ 2.2
4, 1, 5	B	23-lb European	479	462	- 3.5	439	- 8 4	309	308	- 0.3	339	+ 9 7
Average			471	475	+ 0 8	454	- 3.6	268	265	- 1 1	280	+ 4.5
			30.7, 33 0-lb. Linerboard									
10, 7, 11	A	26-lb. U S.	483	486	+ 0.6	495	+ 2.4	284	275	- 3.2	277	- 2.5
10, 7, 11	B	26-lb. U.S.	438	481	+ 9 8	467	+ 6.6	372	335	- 9.9	392	+ 5 4
9, 8, 12	A	23-lb European	482	509	+ 6.2	553	+15.0	272	285	+ 4 8	322	+18.4
9, 8, 12	B	23-lb European	455	471	+ 3.5	465	+ 2 2	359	377	+ 5.0	376	+ 4.7
Average			464	485	+ 4.5	496	+ 6 9	320	316	- 1.3	342	+ 6.9
			35 8, 38.0-lb. Linerboard									
15, 14, 18	A	26-lb U S.	476	492	+ 3.4	521	+ 9 5	286	301	+ 5 2	283	- 1 0
15, 14, 18	B	26-lb. U.S	442	491	+11.1	496	+12.2	397	418	+ 5.3	396	- 0 3
16, 13, 17	A	23-lb European	492	521	+ 5.9	530	+ 7.7	283	342	+20.8	302	+ 6 7
16, 13, 17	B	23-lb. European	443	554	+25.1	482	+ 6.5	387	424	+ 9.7	339	-12.4
Average			464	514	+12.9	508	+ 9 5	337	369	+ 9,5	330	- 2.1
			41 0, 42.0-lb. Linerboard									
23, 19, 22	A	26-lb U S	504	573	+13.7	531	+ 5 4	316	336	+ 6 3	333	+ 5 4
23, 19, 22	B	26-lb. U S	445	492	+11.7	472	+ 6 1	422	440	+ 4 3	451	+ 6.9
24. 20, 21	A	23-lb European	527	579	+ 9 9	512	- 2 8	320	370	+15.6	352	+10 0
24, 20, 21	B	23-lb European	422	496	+17 5	504	+ 4.3	451	446	- 1 1	461	+ 2 2
Average			475	537	+13 1	505	+ 6 3	375	398	+ 6 1	398	+ 6 1

[a] See Note Table III.



3a. Comparison of Average Difference in Box Compression Performance

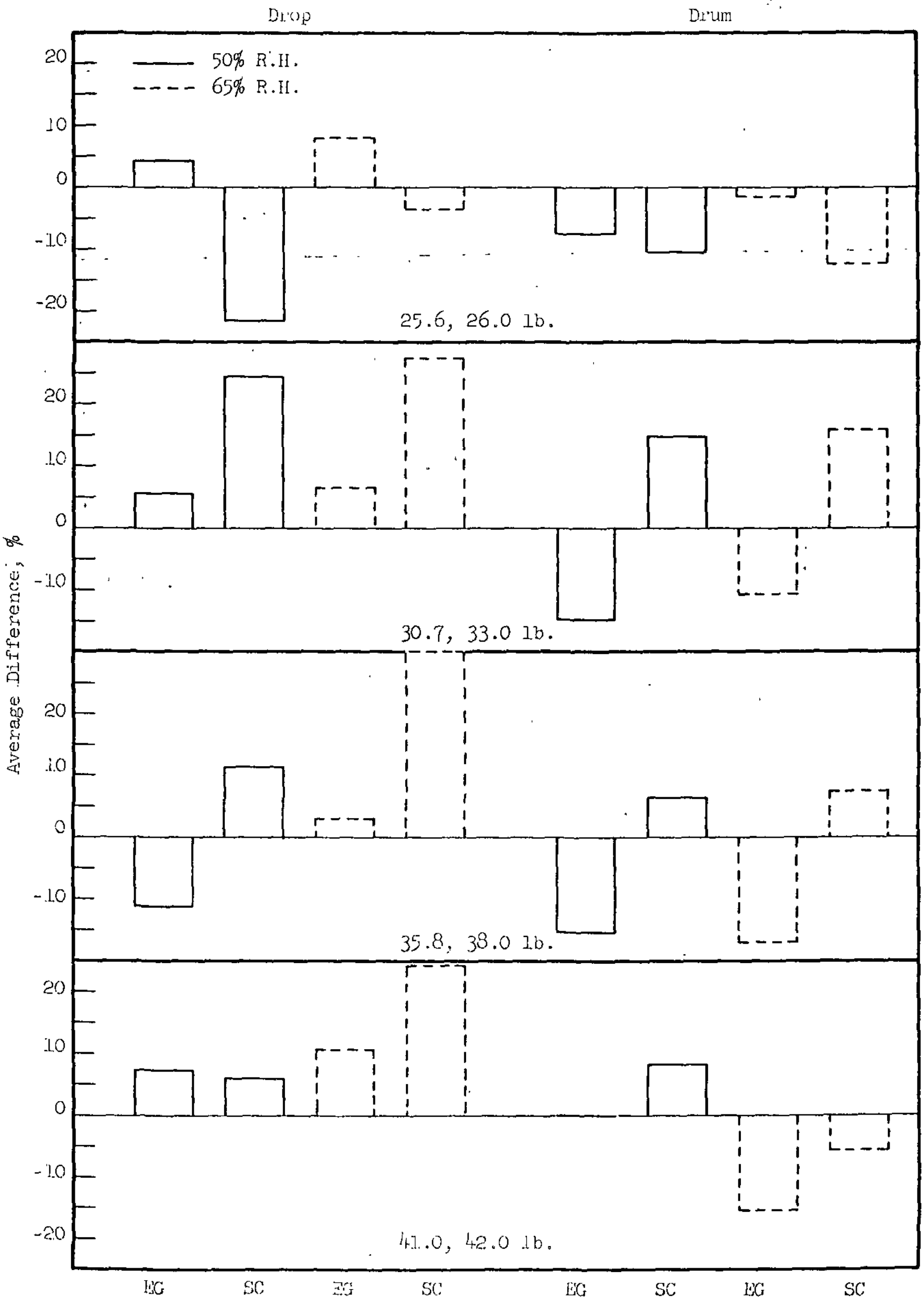


Figure 3b. Comparison of Average Difference in Rough Handling Performance on Equal Weight Basis

The comparative end-load compression performance of boxes made with domestic and European linerboards at four different linerboard grade weight levels may be seen from a comparison of the results tabulated in Tables III and IV and graphically illustrated in Fig. 2a. It may be seen that at the 25.6, 26.0-lb. linerboard grade weight level the composite average end-load compression result on boxes made with U.S. linerboard is approximately [illegible].0% higher than the corresponding result for boxes made with Enso Gutseit linerboard and approximately the same as the boxes made with Svenska Cellulosa linerboard. The differences are not statistically significant; thus it appears that at this level of linerboard weight there is no difference in end-load box compression. In contrast, it may be recalled that at this weight level the U.S. linerboard boxes exhibited significantly higher top-load compression on a box basis.

At the 30.7, 33.0-lb. linerboard grade weight level the boxes made with U.S. linerboard exhibit higher end-load box compression results than the boxes made with European linerboards. The boxes made with U.S. linerboard averaged 5.3 and 6.6% higher, respectively, at 50 and 65% R.H. than the corresponding results on boxes made with Enso Gutseit linerboard. These differences are found to be statistically significant. In contrast, the boxes made with Svenska Cellulosa linerboard averaged only 2.8 and 0.8% lower than the corresponding U.S. linerboard boxes. These differences are not significant. When the results at 35.8, 38.0-lb. linerboard grade weight level are compared, it may be seen that the boxes made with U.S. linerboard exhibit end-load compression results 2.2 and [illegible].9% lower, respectively, at 50 and 65% R.H. than the corresponding boxes made with Enso Gutseit linerboard, but 8.9 and 7.1% higher, respectively, at 50 and 65% R.H. than the boxes made with Svenska Cellulosa linerboard. The composite average difference noted between U.S. and Enso Gutseit linerboard boxes at 50%

R.H. is not statistically significant whereas the corresponding difference at 65% R.H. is significant. The average differences noted between U.S. and Svenska Cellulosa boxes are significant at each humidity. At the 41.0, 42.0-lb. linerboard grade weight level the boxes made with U.S. linerboard exhibit lower end-load results on the average than the corresponding boxes made with European linerboards; however, the differences noted are statistically significant only for the boxes made with Enso Gutseit linerboard and tested at 50% R.H.

On the basis of the end-load box compression results obtained on the boxes fabricated and evaluated in this study, it appears that at the lowest linerboard weight level the boxes made with European linerboards exhibit the same level of end-load compression as the boxes made with U.S. linerboard. In contrast, top-load compression at this linerboard grade weight level is higher for the boxes made with U.S. linerboard. At the 30.7, 33.0-lb. grade weight level the boxes made with Enso Gutseit and Svenska Cellulosa linerboards exhibited lower end-load compression than the boxes made with U.S. linerboard. In contrast, there was, on the average, no significant difference in top-load compression strength between boxes made with European and U.S. linerboards. At the 35.8, 38.0-lb. linerboard grade weight level the boxes made with Enso Gutseit linerboard are slightly higher in end-load compression than the boxes made with U.S. linerboard; whereas the boxes made with Svenska Cellulosa linerboard are significantly lower in end-load compression than the boxes made with U.S. linerboard. Relative to the top-load compression of boxes made with U.S. linerboard, the top-load compression of boxes made with Enso Gutseit linerboard was approximately 7% higher, whereas that of boxes made with Svenska Cellulosa linerboard was equal or slightly ~~lower~~ higher. The end-load compression of the boxes made with Svenska Cellulosa linerboard at the 41.0, 42.0-lb. linerboard grade weight level is not significantly different from the results on the boxes made with U.S. linerboard.

In general, the same behavior was noted for top-load compression. The end-load results for the boxes made with Enso Gutseit linerboard average 4-7% higher than the results obtained on the boxes made with U.S. linerboard, although the differences are statistically significant only at 50% R.H. The same behavior was noted for top-load except that the differences were statistically significant at both 50 and 65% R.H.

In order to adjust for the difference in weight, the end-load compression results tabulated in Tables III and IV have been converted to pounds compression per unit weight of combined board. The compression results on a unit weight basis are tabulated in Tables V and VI and graphically illustrated in Fig. 3a.* It may be noted that on a unit weight basis the results at the 25.6, 26.0-lb. grade weight level appear not to be significantly different. This is the same as was noted earlier when the results were compared on a box basis. On a unit weight basis, at the 30.7, 33.0-lb. grade weight level, the end-load compression results for the boxes made with Enso Gutseit linerboard are approximately the same as for the boxes made with U.S. linerboard. It may be recalled that on a box basis, the compression for the U.S. linerboard boxes was significantly higher. The boxes made with Svenska Cellulosa linerboard, in general, exhibit higher end-load compression than boxes made with U.S. linerboard because of the lower weight, whereas on a box basis there was no significant difference. When the results at the 35.8, 38.0-lb. grade weight level are considered, it may be noted that on a unit weight basis the end-load compression for the boxes made with Enso Gutseit linerboard are significantly higher, whereas the results for the boxes made with Svenska Cellulosa linerboard are, on the average, lower than the corresponding results for the boxes made with U.S. linerboard. The same trend was found when compared on a box basis. On a unit weight basis at the 41.0, 42.0-lb. grade weight level, the boxes made with Enso

* See page 45.

Gutseit and Svenska Cellulosa linerboards exhibit higher end-load compression than the corresponding boxes made with U.S. linerboard. The same trend was noted on a box basis; however, the differences were not significant except in one case – Enso Gutseit linerboard boxes at 50% R.H.

2. Rough Handling Performance

Rough handling, which is one of the major categories of end-use requirements, is evaluated in this study in terms of corner drop and drum tests. For purposes of this study, the end-point used is the number of drops or falls, as the case may be, which the box resisted prior to failure as denoted by a spilling of the contents which in this case consisted of 24, No. 12-ounce cans filled with water. It should be emphasized in interpreting drop and drum results that these tests are impact fatigue tests and both fatigue and impact tests are characterized by high variability; thus, it is to be expected that greater differences in test results may occur by chance than was noted for box compression. Saying it another way, greater differences may be expected before they are significantly different.

The drop and drum results obtained at 50 and 65% R.H. are tabulated in Tables VII and VIII, respectively, and illustrated in Fig. 2b*. The drop and drum results have been analyzed by the same statistical technique as was used with the compression results for the purpose of determining if the composite averages at a given grade weight level are significantly different or whether the observed difference could occur by chance due to the variability associated with the materials and methods of evaluation.

It may be noted from the results tabulated in Tables VII and VIII and illustrated in Fig. 2b*, that at the 25.6, 26.0-lb. grade weight level the average drop results for the boxes at 50 and 65% R.H. made with U.S. linerboard are

*See page 39.

TABLE VII

ROUGH HANDLING PERFORMANCE

(50% Relative Humidity)

			Corner Drop, drop					Drum, fall				
Run	Flute	Type Medium	US Liner	EG Liner	Diff , % [a]	SC Liner	Diff , % [a]	US Liner	EG Liner	Diff , % [a]	SC Liner	Diff., % [a]
					25 6, 26.0-lb Linerboard							
3, 2, 6	A	26-lb U S	9 1	9 4	+ 3 3	6 5	-28 6	84	77	- 8 3	75	-10 7
3. 2. 6	B	26-lb U S	6 2	6 1	- 1 6	5 0	-19 4	56	56	0 0	51	- 8 9
4, 1, 5	A	23-lb European	6 6	6 9	+ 4 5	5.0	-24 2	67	45	-32 8	67	0 0
4, 1, 5	B	23-lb European	4 8	5 1	+ 6 2	3 8	-20 8	45	48	+ 6 7	25	-44 4
Average			6 7	6 9	. 3 0(N S) [b]	5.1	-23 9(01)	63	57	- 9 5(N S)	55	-12 7(N S)
					30 7, 33 0-lb Linerboard							
10, 7, 11	A	26-lb U S.	10 1	9 4	- 6 9	10 5	+ 4 0	110	99	-10 0	118	+ 7 3
10, 7, 11	B	26-lb U S.	6 5	6.8	+ 4 6	8 2	+26.2	63	62	- 1 6	87	+38 1
9, 8, 12	A	23-lb European	8.7	7 8	-10.3	10 5	+20.7	110	56	-49.1	87	-20 9
9, 8, 12	B	23-lb European	5.6	6 6	+17 9	6.8	+21 4	42	43	+ 2 4	60	+42 9
Average			7.7	7 7	0 0(N S.)	9.0	+16.9(01)	81	65	-19 8(.01)	88	+ 8 6(N S.)
					35 8, 38 0-lb Linerboard							
15, 14, 18	A	26-lb U S	12.2	10 8	-11 5	13 8	+13.1	154	122	-20 8	146	- 5 2
15, 14, 18	B	26-lb. U. S.	10 1	8.5	-15 8	11.2	+10.9	88	76	-13 6	116	+31.8
16, 13, 17	A	23-lb. European	11 6	8 9	-23.3	11.0	- 5.2	120	91	-24.2	106	-11.7
16, 13, 17	B	23-lb. European	8 2	7.7	- 6 1	8.7	+ 6.1	74	68	- 8.1	74	0 0
Average			10 5	9 0	-14 3(.01)	11 2	+ 6.7(N S.)	109	89	-18.3(01)	111	+ 1.8(N.S)
					41, 42-lb. Linerboard							
23, 19, 22	A	26-lb. U S	13 3	13 2	- 0.8	12.7	- 4 5	144	151	+ 4.9	141	- 2.1
23, 19, 22	B	26-lb. U. S.	9 9	9.6	- 3.0	10 7	+ 8 1	94	96	+ 2.1	82	-12 8
24, 20, 21	A	23-lb European	10 4	11 5	+11.5	10.1	- 2 9	110	107	- 2 7	116	+ 5 5
24, 20, 21	B	23-lb European	8 0	9 2	+15 0	8.9	+11.2	77	54	-29.9	95	+23.4
Average			10.4	10.9	+ 4.9(N S)	10 6	+ 1 9(N S.)	106	102	- 3 7(N.S)	109	+ 2 8(N S)

[a] Based on U. S liner results as reference

[b] Value in parenthesis indicates significance level: (.01) means difference is significant at 1% level, (05) significant at 5% level, (N.S.) difference not statistically significant at 1 or 5% level

TABLE VIII

ROUGH HANDLING PERFORMANCE

(65% Relative Humidity)

Run	Flute	Type Medium	Corner Drop, drop U.S. Liner	E.G. Liner	Diff., % [a]	S.C. Liner	Diff., % [a]	Drum, fall U.S. Liner	E.G. Liner	Diff., % [a]	S. C. Liner	Diff., % [a]
					25.6, 26.0-lb. Linerboard							
3, 2, 6	A	26-lb. U. S.	11.4	11.3	- 0.9	10.9	- 4.4	92	82	-10.9	81	-12.0
3, 2, 6	B	26-lb. U. S.	8.6	9.2	+ 7.0	7.1	-17.4	52	55	+ 5.8	50	- 3.8
4, 1, 5	A	23-lb. European	8.1	8.6	+ 6.2	7.4	- 8.6	62	55	-11.3	53	-14.5
4, 1, 5	B	23-lb. European	6.9	7.3	+ 5.8	6.8	- 1.4	51	54	+ 5.9	33	-35.3
Average			8.8	9.1	+ 3.4(N.S.)[b]	8.0	- 9.1(N S.)	64	62	- 3.1(N S.)	54	-15.6(.05)
					30.7, 38.0-lb. Linerboard							
10, 7, 11	A	26-lb. U. S.	13.0	12.0	- 7.7	14.4	+10.8	99	93	- 6.1	102	+ 3.0
10, 7, 11	B	26-lb. U. S.	9.1	10.6	+16.5	12.0	+31.9	80	65	-18.8	86	+ 7.5
9, 8, 12	A	23-lb. European	10.4	10.1	- 2.9	14.1	+35.6	106	78	-26.4	102	- 3.8
9, 8, 12	B	23-lb. European	8.9	9.2	+ 3.4	8.8	- 1.1	55	52	- 5.5	76	+38.2
Average			10.4	10.5	+ 1.0(N.S.)	12.3	+18.3(.01)	85	72	-15.3(.01)	92	+ 8.2(N.S.)
					35.8, 38.0-lb. Linerboard							
15, 14, 18	A	26-lb. U. S.	13.6	14.3	+ 5.1	20.1	+47.8	150	105	-30.0	162	+ 8.0
15, 14, 18	B	26-lb. U. S.	12.2	9.9	-18.9	14.0	+14.8	94	75	-20.2	87	- 7.4
16, 13, 17	A	23-lb. European	11.7	12.9	+10.3	13.4	+14.5	118	105	-11.0	126	+ 6.8
16, 13, 17	B	23-lb. European	10.8	11.3	+ 4.6	12.4	+14.8	94	80	-14.9	92	- 2.1
Average			12.1	12.1	0.0(N.S.)	15.0	+24.0(.01)	114	91	-20.2(.01)	117	+ 2.6(N.S.)
					41, 42-lb. Linerboard							
23, 19, 22	A	26-lb. U. S.	15.9	18.4	+15.7	18.6	+17.0	185	154	-16.8	179	- 3.2
23, 19, 22	B	26-lb. U. S.	11.9	13.9	+16.8	13.1	+10.1	104	110	+ 5.8	101	- 2.9
24, 20, 21	A	23-lb. European	12.9	13.5	+ 4.7	17.3	+34.1	153	97	-36.6	113	-26.1
24, 20, 21	B	23-lb. European	11.7	11.9	+ 1.7	13.8	+17.9	98	92	- 6.1	93	- 5.1
Average			13.1	14.4	+ 9.9(N.S.)	15.7	+19.8(.01)	135	113	-16.3(.05)	122	- 9.6(N.S.)

[a] Based on U. S. liner results as reference.

[b] Value in parenthesis indicates significance level: (.01) means difference is significant at 1% level; (.05) significant at 5% level; (N.S.) difference not statistically significant at 1 or 5% level.

slightly lower than the corresponding results for boxes made with Enso Gutseit linerboard, however, the differences are too small to be statistically significant The drop results for the boxes made with Svenska Cellulosa linerboards are considerably lower at 50 and 65% R.H than the corresponding results on the boxes made with U S linerboard, however, only the differences at 50% R.H. are statistically significant. The drop results at the 30.7, 33.0-lb grade weight level for the boxes made with U.S. linerboard and tested at 50 and 65% R H. are approximately equal to the corresponding results for the boxes made with Enso Gutseit linerboard On the other hand, the drop results obtained on the boxes made with Svenska Cellulosa linerboard are significantly higher, 16.9 and 18.3%, respectively, at 50 and 65% R H. than the corresponding results obtained on boxes made with U.S linerboard.

At the 35 8, 38 0-lb grade weight level there is no clearly defined trend The drop results on boxes made with U.S. linerboard and tested at 50% R H are significantly higher (14.3%) than the corresponding results obtained on the boxes fabricated with Enso Gutseit linerboard, at 65% R.H. the composite percentages are equal In contrast, the drop results for the boxes made with Svenska Cellulosa linerboard are higher, 6 7 and 24 0%, respectively, at 50 and 65% R H , than the corresponding results for boxes made with U.S. linerboard, however, only the results at 65% R.H. are statistically significant. The drop results at 41 0, 42 0-lb grade weight level for boxes made with U S linerboard are, on the average, lower than the corresponding results for boxes made with the other linerboards. However, only the results for the boxes made with Svenska Cellulosa linerboard and tested at 65% R.H. are statistically higher than the corresponding results for the boxes made with U S. linerboard

Because of the disparity in the weight of European and domestic liner-board the drop test results tabulated in Tables VII and VIII have been converted to a unit weight basis in order that the drop test performance may be compared on the same weight basis. The drop test results on a unit weight basis are tabulated in Tables IX and X and illustrated in Fig 30.* It may be seen that at the 25.6, 26.0-lb. grade weight level the trend is the same as was noted on the box basis – namely, the drop results on the boxes made with Enso Gutseit liner-board average slightly higher and those for the boxes made with Svenska Cellulosa linerboard lower than the results for the corresponding boxes made with U.S. linerboard It is doubtful if the differences are significant, except that for the Svenska Cellulosa linerboard boxes at 50% R.H., wherein the results are 21.4% lower than for the U.S. linerboard boxes

When the drop results at 30.7, 33 0-lb. grade weight level are converted to a unit weight basis, it may be noted that, on the average, the results for boxes made with U.S. linerboard are slightly lower than the results for the boxes made with Enso Gutseit linerboard. On the other hand, the corresponding results for the boxes made with Svenska Cellulosa linerboard average approximately [illegible] and 27% higher at 50 and 65% R H These latter differences are believed to be significant

As in the case of the results at the two weight levels described above, adjusting for weight at the 35.7, 38.0-lb. grade weight level has the effect of increasing the difference noted on a box basis. The drop results on a per unit basis for the boxes made with Enso Gutseit linerboard range from an average of 11.2% lower to 3.0% higher at 50 and 65% R H., respectively, than the corresponding results for the boxes made with U.S linerboard The difference of 11 2% is probably on the borderline of significance whereas the 3 0% difference is too

*See page [illegible].

TABLE IX

COMPARISON OF ROUGH HANDLING PERFORMANCE PER UNIT WEIGHT COMBINED BOARD
(50% Relative Humidity)

			Corner Drop, Drops/100-lb. Combined Board Weight					Drum, Falls/100-lb. Combined Board Weight				
Run	Flute	Type Medium	U.S. Liner	E.G. Liner	Diff.,[a] %	S.C. Liner	Diff.,[a] %	U.S. Liner	E.G. Liner	Diff.,[a] %	S.C. Liner	Diff.,[a] %
					25.6, 26.0-lb. Linerboard							
3, 2, 6	A	26-lb. U.S.	8.9	9.5	+ 6.7	6.7	-24.7	82	78	- 4.9	77	- 6.1
3, 2, 6	B	26-lb. U.S.	6.6	6.5	- 1.5	5.3	-19.7	60	60	0.0	54	-11.1
4, 1, 5	A	23-lb. European	6.8	7.3	+ 7.4	5.4	-20.6	69	48	-20.0	72	+ 4.3
4, 1, 5	B	23-lb. European	5.3	5.7	+ 7.5	4.3	-18.9	49	54	+10.2	28	-42.9
Average			7.0	7.3	+ 4.3	5.5	-21.4	66	61	- 7.6	59	-10.6
					30.7, 33.0-lb. Linerboard							
10, 7, 11	A	26-lb. U.S.	8.9	8.7	- 2.2	9.8	+10.1	96	92	- 4.2	110	+14.6
10, 7, 11	B	26-lb. U.S.	5.9	6.5	+10.2	7.9	+33.9	57	59	+ 3.5	84	+47.4
9, 8, 12	A	23-lb. European	8.0	7.5	- 6.3	10.2	+27.5	101	54	-46.5	84	-16.8
9, 8, 12	B	23-lb. European	5.3	6.6	+24.5	6.9	+30.2	40	43	+ 7.5	61	+52.5
Average			7.0	7.4	+ 5.7	8.7	+24.3	74	63	-14.9	85	+14.9
					35.8, 38.0-lb. Linerboard							
15, 14, 18	A	26-lb. U.S.	9.9	9.1	- 8.1	11.7	+18.2	125	103	-17.6	124	- 0.8
15, 14, 18	B	26-lb. U.S.	8.5	7.4	-12.9	9.8	+12.1	74	67	- 9.5	102	+37.8
16, 13, 17	A	23-lb. European	9.8	7.8	-20.4	9.7	- 1.0	102	80	-21.6	94	- 7.8
16, 13, 17	B	23-lb. European	7.3	7.1	- 2.7	8.1	+11.0	65	62	- 4.6	69	+ 6.2
Average			8.9	7.9	-11.2	9.9	+11.2	92	78	-15.2	98	+ 6.5
					41.0, 42.0-lb. Linerboard							
23, 19, 22	A	26-lb. U.S.	10.2	10.3	+ 1.0	10.2	0.0	111	118	+ 6.3	114	+ 2.7
23, 19, 22	B	26-lb. U.S.	7.9	7.9	0.0	9.1	+15.2	75	79	+ 5.3	69	- 8.0
24, 20, 21	A	23-lb. European	8.3	9.3	+12.0	8.4	+ 1.2	87	90	+ 3.4	97	+11.5
24, 20, 21	B	23-lb. European	6.7	7.7	+15.9	7.7	+14.9	64	45	-31.7	82	+28.1
Average			8.3	8.9	+ 7.2	8.8	+ 6.0	84	84	0.0	91	+ 8.3

[a] See Note Table III.

TABLE X

COMPARISON OF ROUGH HANDLING PERFORMANCE PER UNIT WEIGHT COMBINED BOARD
(65% Relative Humidity)

Run	Flute	Type Medium	Corner Drop, Drops/100-lb Combined Board Weight					Drum, Falls/100-lb. Combined Board Weight				
			U S Liner	E.G Liner	Diff ,[a] %	S.C Liner	Diff.,[a] %	U.S. Liner	E G. Liner	Diff.,[a] %	S C. Liner	Diff.,[a] %
			25 6, 26.0-lb. Linerboard									
3, 2, 6	A	26-lb. U S.	11 0	11.2	+ 1.8	11.0	0.0	89	81	- 8.2	82	- 7.6
3, 2, 6	B	26-lb U S	8.8	9.6	+ 9.1	7.4	-15.9	53	57	+ 7.5	52	- 1 9
4, 1, 5	A	23-lb European	8 2	9.0	+ 9.8	7.8	- 4.9	63	57	- 9.5	56	-11.1
4, 1, 5	B	23-lb European	7.3	8.0	+ 9.6	7.6	+ 4.1	54	59	+ 9 3	37	-31 5
Average			8 8	9.5	+ 8.0	8 5	- 3.4	65	64	- 1 5	57	-12.3
			30.7, 33 0-lb. Linerboard									
10, 7, 11	A	26-lb. U S.	11 2	10.8	- 3.6	13.1	+17 0	85	84	- 1.2	93	+ 9.4
10, 7, 11	B	26-lb U S	8.1	10 0	+23.5	11 3	+39 5	71	61	-14.1	81	+14 1
9, 8, 12	A	23-lb European	9 3	9.4	+ 1.1	13 6	+46 2	95	73	-23.2	98	+ 3.2
9, 8, 12	B	23-lb European	8.1	9.0	+11.1	8.7	+ 7 4	50	51	+ 2.0	75	+50 0
Average			9 2	9.8	+ 6.5	11 7	+27.2	75	67	-10 7	87	+16.0
			35.8, 38.0-lb. Linerboard									
15, 14, 18	A	26-lb U S	10 8	11.6	+ 7.4	16 8	+55 6	119	85	-28 6	135	+13.5
15, 14, 18	B	26-lb. U S.	10.1	8.5	-15.8	12.2	+20.8	78	65	-16 7	76	- 2.6
16, 13, 17	A	23-lb. European	9.6	11.0	+14.6	11.6	+20.8	97	90	- 7 2	109	+12.4
16, 13, 17	B	23-lb European	9 4	10 1	+ 7.4	11.4	+21.3	82	71	-13 4	84	+ 2.4
Average			10.0	10 3	+ 3 0	13.0	+30.0	94	78	-17.0	101	+ 7 4
			41 0, 42.0-lb. Linerboard									
23, 19, 22	A	26-lb. U S	12.0	14 0	+16.7	14.4	+20.0	139	118	-15.1	139	0 0
23, 19, 22	B	26-lb. U S.	9.3	11.0	+18.3	10.7	+15 1	81	87	+ 7 4	82	+ 1 2
24, 20, 21	A	23-lb European	10.1	10.6	+ 5.0	14.2	+40.6	120	76	-36.7	93	-22.5
24, 20, 21	B	23-lb European	9 6	9.8	+ 2.1	12.0	+25.0	80	76	- 5.0	81	+ 1 3
Average			10.3	11 4	+10.7	12 8	+24.3	105	89	-15 2	99	- 5 7

[a] See Note Table III.

small to be significant. In the case of the boxes made with Svenska Cellulosa linerboard, the drop results are 11 2 and 30 0% higher than the corresponding results for the boxes made with U.S. linerboard These latter differences range from borderline significance to positive significance

At the 41.0, 42.0-lb grade weight level there appear to be no significant differences in the composite average drop test for the boxes made with European and domestic linerboards except for the boxes made with Svenska Cellulosa linerboard and evaluated at 65% R H., the latter results indicating that the boxes made with Svenska Cellulosa linerboard are better in terms of rough handling than the corresponding boxes made with U.S. linerboard It is difficult to understand why the results at 65% R H are significantly different whereas the results at 50% R H are not.

The results of the drum tests on the boxes made in connection with this study at 50 and 65% R.H. are tabulated in Tables VII and VIII, respectively, and graphically illustrated in Fig 2b.* It may be seen from the results tabulated in Tables VII and VIII and illustrated in Fig. 2b* that at the 25.6, 26.0-lb grade weight level, the boxes made with U.S. linerboard exhibited higher average drum performance than the boxes made with European linerboards However, the differences noted were not statistically significant except for the boxes made with Svenska Cellulosa linerboard and evaluated at 65% R.H. and then only at the 5% level At the 30.7, 33 0-lb. grade weight level the drum results obtained on boxes made with U.S. linerboard are higher on the average at both 50 (19 8%) and 65 ([illegible]%) R H. than the boxes made with Enso Gutseit linerboard. The differences were statistically significant In contrast, the results obtained on boxes made with Svenska Cellulosa linerboard are slightly higher on the average at both 50% ([illegible]) and 65% (8 2%) R H. than boxes made with U.S linerboard. These differences

* See page 59

are not significant, thus it appears that the boxes made with U.S. linerboard give drum performance approximately equivalent to the boxes made with Svenska Cellulosa linerboard.

When the drum results obtained on boxes made with 35.7-lb. European linerboards are compared with the corresponding results obtained on boxes made with 38.0-lb. U.S. linerboard, it may be seen that the boxes made with Enso Gutseit linerboard exhibit significantly lower drum performance than the boxes made with U.S. linerboard. The average differences were 18.3 and 20.2%, respectively, for 50 and 65% R.H. In contrast, the boxes made with Svenska Cellulosa linerboard averaged 1.8 and 2.6% higher, respectively, at 50 and 65% R.H. than the boxes made with U.S. linerboard. These differences, however, are not statistically significant. Therefore, at the 35.7, 38.0-lb. grade weight level the boxes made with Enso Gutseit linerboards are significantly lower in drum performance than boxes made with U.S. linerboard. Boxes made with Svenska Cellulosa linerboard give approximately the same drum performance as boxes made with U.S. linerboard.

At the 41.0, 42.0-lb. grade weight level, the drum results on boxes made with Enso Gutseit linerboard average 3.7 and 16.3% lower, respectively, at 50 and 65% R.H. than the boxes made with U.S. linerboard. The 16.3% difference is statistically significant whereas the difference of 3.7% does not represent a significant difference. The drum results obtained on the boxes made with Svenska Cellulosa linerboard averaged 2.8% higher at 50% R.H. and 9.6% lower at 65% R.H. than the corresponding results for boxes made with U.S. linerboard. Neither of these differences is great enough to represent a significant difference in drum performance.

Because of the difference in the nominal grade weight of competitive grades of European and domestic linerboard, the drum results tabulated in Tables VII and VIII have been converted to a unit weight basis in order to compare performance at the same weight. The drum results calculated on a unit weight basis are tabulated in Tables IX and X, respectively, for 50 and 65% R H and are illustrated in Fig. 3b*.

At the 25.6, 26.0-lb. grade weight level the results obtained on boxes fabricated with U.S linerboard are slightly higher than for boxes made with European linerboards. The differences, however, are not considered significant

When the results obtained at the 30 7, 33 0-lb grade weight level are considered it may be seen that the boxes made with Svenska Cellulosa linerboard average 15-16% higher at 50 and 65% R.H. than for the boxes made with U S linerboard. The drum results of the boxes made with Enso Gutseit linerboard are [illegible] 9 and 10.7% lower, respectively, at 50 and 65% R H

At the 35 8, 38 0-lb. grade weight level the boxes made with U S [illegible] board average 15 2 and 17 0% higher than the results for the boxes made [illegible] Enso Gutseit linerboard, however, these differences are probably border[illegible] terms of significant differences in drum performance on a unit weight [illegible] The results for boxes made with Svenska Cellulosa linerboard average [illegible] 7 4% higher than the corresponding results for U S linerboard boxes, [illegible], these differences are not significant

The results obtained at the 41.0, 42.0-lb grade weight level [illegible] [illegible] results on boxes made with U.S linerboard average 0 to 15% higher than [illegible] results for boxes made with Enso Gutseit linerboard These differences are [illegible] not significant The corresponding results for boxes made with Svenska

[illegible]

Cellulosa linerboard show no significant differences relative to boxes made with U.S. linerboard.

To provide a convenient synopsis of the preceding discussion, the data presented in Tables III through X relative to the comparative performance of boxes fabricated with European and domestic linerboards are summarized in Table XI in terms of the composite average differences at each grade weight level on the basis of (a) actual box performance, and (b) on a unit weight basis.

C. Comparative Performance of Boxes Fabricated with European Linerboards

The results presented earlier for boxes made with Enso Gutseit and Svenska Cellulosa linerboards have been retabulated in Tables XII-XV in order to make a direct comparison of their performance.

1. Compression Performance

The box compression results are tabulated in Table XII and illustrated in Fig. 4a. Based on the composite averages at each linerboard weight level, it may be seen that boxes made with Enso Gutseit linerboard give equal or slightly higher top-load compression at the 25.6-lb. linerboard grade weight level, but lower end-load compression than boxes made with Svenska Cellulosa linerboard. The same general trend also applies to the performance at the 30.7-lb. linerboard grade weight level. At the 35.8-lb. and 41.0-lb. linerboard grade weight levels, boxes made with Enso Gutseit linerboard appear to be slightly superior in terms of both top- and end-load performance than boxes made with Svenska Cellulosa linerboard.

In order to compare compression performance on a unit combined board weight basis, the results tabulated in Table XII have been converted to a unit weight basis by dividing box compression by the corresponding combined board

TABLE XI

SUMMARY OF BOX PERFORMANCE - COMPOSITE AVERAGE DIFFERENCES

Relative Humidity, %	Composite Average Difference on Box Basis: Top Compression, Difference[a], % E G	Top Compression S C	End Compression, Difference[a], % E G	End Compression S C	Drop Performance Difference[a], % E G	Drop Performance S C	Drum Performance, Difference[a], % E G	Drum Performance S C	Composite Average Difference on Unit Combined Board Weight: Top Compression, Difference[a], % E G	Top Compression S C	End Compression, Difference[a], % E G	End Compression S C	Drop Performance, Difference[a], % E G	Drop Performance S C	Drum Performance, Difference[a], % E G	Drum Performance S C
							25.6, 26.0-lb Linerboard									
50	-5.3(.01)	-5.1(.01)	-4.1(NS)	-0.7(NS)	+3.0(NS)	-23.9(.01)	-9.5(NS)	-12.7(NS)	-3.2	-1.7	-1.9	+1.9	+4.3	-21.4	-7.6	-10.6
65	-2.1(NS)	-7.5(.01)	-4.2(NS)	+0.4(NS)	+3.4(NS)	-9.1(NS)	-3.1(NS)	-15.6(.05)	+0.8	-3.6	-1.1	+4.5	+8.0	-3.4	-1.5	-12.3
							30.7, 33.0-lb Linerboard									
50	+1.6(.01)	0.0(NS)	-5.3(.01)	-2.8(NS)	0.0(NS)	+16.9(.01)	-19.8(.01)	+8.6(NS)	+7.5	+6.8	+0.3	+4.1	+5.7	+24.3	-14.9	+14.9
65	-1.0(NS)	-0.6(NS)	-6.6(.01)	-0.8(NS)	+1.0(NS)	+18.3(.01)	-15.3(.01)	+8.2(NS)	+4.5	+6.9	-1.3	+6.9	+6.5	+27.2	-10.7	+16.0
							35.8, 38.0-lb Linerboard									
50	+7.4(.01)	+1.0(NS)	+2.2(NS)	-8.9(.01)	-14.3(.01)	+6.7(NS)	-18.3(.01)	+1.8(NS)	+11.1	+5.5	+5.8	-5.0	-11.2	+11.2	-15.2	+6.5
65	-7.1(.01)	+4.1(.01)	+5.9(.01)	-7.1(.01)	0.0(NS)	+24.0(.01)	-20.2(.01)	+2.6(NS)	+12.9	+9.5	+9.5	-2.1	+3.0	+30.0	-17.0	+7.4
							41.0, 42.0-lb Linerboard									
50	+8.7(.01)	+2.7(.01)	-7.1(.01)	+3.8(NS)	+4.9(NS)	+1.9(NS)	-3.7(NS)	+2.8(NS)	+11.3	+9.6	+9.7	+9.0	+7.2	+6.0	0.0	+8.3
65	+[illegible]2(.01)	+1.6(NS)	+4.4(NS)	+1.2(NS)	+9.9(NS)	+19.8(.01)	-16.3(.05)	-9.6(NS)	+13.1	+6.3	+6.1	+6.1	+10.7	+24.3	-15.2	-5.7

[a] Results obtained on boxes made with U S linerboard used as reference, minus and plus prefix means lower and higher than reference, respectively

[b] The value in parenthesis indicate level of significance, NS means observed difference not significant

TABLE XII

COMPARISON OF BOX COMPRESSION PERFORMANCE OF BOXES MADE WITH EUROPEAN LINERBOARDS

Run	Flute	Type Medium	Top-Load Compression (0-0 75 in), lb: 50% R H E G Liner	50% R H S C Liner	50% R H Diff., %[a]	65% R H E G Liner	65% R H S C Liner	65% R H Diff., %[a]	End-Load Compression (0-0 75 in), lb.: 50% R H E G Liner	50% R H S C Liner	50% R H Diff., %[a]	65% R H E G Liner	65% R H S C Liner	65% R H Diff., %[a]
25 6-lb Linerboard														
2, 6	A	26-lb U S	510	520	+ 2.0	465	470	+ 1 1	245	255	+ 4.1	210	235	+11 9
2, 6	B	26-lb. U S	445	440	- 1 1	425	405	- 4.7	340	345	+ 1 5	305	305	0 0
1, 5	A	23-lb European	520	530	+ 1.9	515	455	-11.7	230	255	+10 9	220	220	0 0
1, 5	B	23-lb European	435	435	0 0	420	395	- 6 0	320	320	0 0	280	305	+ 8 9
Composite			478	481	+ 0.6	456	431	- 5.5	284	294	+ 3 5	254	266	+ 4 7
30 7-lb Linerboard														
7, 11	A	26-lb U S	615	610	- 0 8	540	545	+ 0 9	350	340	- 2.9	305	305	0 0
7, 11	B	26-lb U S	545	525	- 3 7	510	495	- 2 9	410	440	+ 7 3	355	415	+16.9
8, 12	A	23-lb European	595	625	+ 5 0	545	575	+ 5.5	335	355	+ 6 0	305	335	+ 9.8
8, 12	B	23-lb. European	555	515	- 7 2	480	470	- 2 1	415	415	0.0	385	380	- 1 3
Composite			578	569	- 1 6	519	521	+ 0 4	378	388	+ 2 6	338	359	+ 6.2
35 8-lb. Linerboard														
14, 18	A	26-lb U S	690	640	- 7 2	605	625	+ 3.3	405	385	+ 4.9	370	340	- 8 1
14, 18	B	26-lb U S	600	590	- 1.7	570	570	0 0	520	435	-21.0	485	455	- 6.2
13, 17	A	23-lb European	675	630	- 6 7	610	615	+ 0.8	415	390	- 6 0	400	350	-12 5
13, 17	B	23-lb European	635	585	- 7 9	620	525	- 0 8	495	425	- 6 1	475	370	-22 1
Composite			650	611	- 6 0	601	584	- 2 8	459	409	-10.8	432	379	-12 3
41 0-lb. Linerboard														
19, 22	A	26-lb U S	775	715	- 7 7	750	685	- 8.7	470	495	+ 5.3	440	430	- 2 3
19, 22	B	26-lb U S	640	640	0.0	620	580	- 6.5	610	535	-12 3	555	555	0 0
20, 21	A	23-lb. European	815	740	- 9.2	735	625	-15.0	485	490	+ 1 0	470	430	- 8.5
20, 21	B	23-lb. European	630	650	+ 3.2	600	580	- 3.3	600	575	- 4.2	540	530	- 1.9
Composite			715	686	- 4 1	676	618	- 8 6	541	524	- 3 1	501	486	- 3 0

[a] E G liner used as reference

COMPARISON OF BOX COMPRESSION PERFORMANCE ON A UNIT WEIGHT BASIS

Run	Flute	Type Medium	Top-Load Compression, lb./100-lb. Combined Board Weight, 50% R.H., E.G. Liner	50% R.H., S.C. Liner	50% R.H., Diff.,[a] %	65% R.H., E.G. Liner	65% R.H., S.C. Liner	65% R.H., Diff.,[a] %	End-Load Compression, lb./100-lb. Combined Board Weight, 50% R.H., E.G. Liner	50% R.H., S.C. Liner	50% R.H., Diff.,[a] %	65% R.H., E.G. Liner	65% R.H., S.C. Liner	65% R.H., Diff.,[a] %
					25.6-lb. Linerboard									
[illegible], 6	A	26-lb. U.S.	515	536	+ 4.1	460	475	+ 3.3	247	263	+ 6.5	208	237	+13.9
[illegible], 6	B	26-lb. U.S.	473	469	- 0.8	443	422	- 4.7	362	367	+ 1.4	318	318	0.0
[illegible], 5	A	23-lb. European	553	570	+ 3.1	536	479	- 8.0	245	274	+11.8	229	232	+ 1.3
[illegible], 5	B	23-lb. European	489	489	0.0	462	439	- 5.0	360	359	- 0.3	308	339	+10.1
Composite			509	517	+ 1.6	475	454	- 4.4	302	316	+ 4.6	265	280	+ 5.7
					30.7-lb. Linerboard									
[illegible], 11	A	26-lb. U.S.	569	570	+ 0.2	486	495	+ 1.9	324	318	- 1.9	275	277	+ 0.7
[illegible], 11	B	26-lb. U.S.	519	505	- 2.7	481	467	- 2.9	390	423	+ 8.5	335	392	+17.0
[illegible], 12	A	23-lb. European	572	607	+ 6.1	509	553	+ 8.6	322	345	+ 7.1	285	322	+13.0
[illegible], 12	B	23-lb. European	555	526	- 5.2	471	465	- 1.3	415	423	+ 1.9	377	376	- 0.3
Composite			556	552	- 0.7	485	496	+ 2.3	363	377	+ 3.9	316	342	+ 8.2
					35.8-lb. Linerboard									
[illegible] 18	A	26-lb. U.S.	580	542	- 6.6	492	521	+ 5.9	340	326	- 4.1	301	283	- 6.0
[illegible], 18	B	26-lb. U.S.	526	518	- 1.5	491	496	+ 1.0	456	382	-16.2	418	396	- 5.3
[illegible] 17	A	23-lb. European	592	558	- 5.7	521	530	+ 1.7	364	345	- 5.2	342	302	-17.5
[illegible] 17	B	23-lb. European	583	547	- 6.2	554	482	- 5.1	454	397	- 9.5	424	339	- 3.5
Composite			570	541	- 5.1	514	508	- 1.2	403	362	-10.2	369	330	-10.6
					41.0-lb. Linerboard									
19, 22	A	26-lb. U.S.	605	577	- 4.6	573	531	- 7.3	367	399	+ 8.7	336	333	- 0.9
19, 22	B	26-lb. U.S.	525	542	+ 3.2	492	472	- 4.1	500	453	- 9.2	440	451	+ 2.5
20, 21	A	23-lb. European	663	617	- 6.9	579	512	-11.6	394	408	+ 3.6	370	352	- 4.9
20, 21	B	23-lb. European	529	560	+ 5.9	496	504	+ 1.6	504	496	- 1.6	446	461	+ 3.4
Composite			581	572	- 1.5	537	505	- 6.0	440	437	- 0.7	398	398	0.0

[a] E.G. liner used as reference.

TABLE XIV

COMPARISON OF ROUGH HANDLING PERFORMANCE OF BOXES MADE WITH EUROPEAN LINERBOARD

			Drop Performance, drop						Drum Performance, fall					
			50% R.H.			65% R.H.			50% R.H.			65% R.H.		
Run	Flute	Type Medium	E.G. Liner	S.C. Liner	Diff., % [a]	E.G. Liner	S.C. Liner	Diff., % [a]	E.G. Liner	S.C. Liner	Diff., % [a]	E.G. Liner	S.C. Liner	Diff., % [a]
25.6-lb. Linerboard														
2, 6	A	26-lb. U.S.	9.4	6.5	-30.9	11.3	10.9	- 3.5	77	75	- 2.6	82	81	- 1.2
2, 6	B	26-lb. U.S.	6.1	5.0	-18.0	9.2	7.1	-22.8	56	51	- 8.9	55	50	- 9.1
1, 5	A	23-lb. European	6.9	5.0	-27.5	8.6	7.4	-14.0	45	67	+48.9	55	53	- 3.6
1, 5	B	23-lb. European	5.1	3.8	-25.5	7.3	6.8	- 6.8	48	25	-47.9	54	33	-38.9
Composite			6.9	5.1	-26.1	9.1	8.0	-10.0	57	55	- 3.5	62	54	-12.9
30.7-lb. Linerboard														
7, 11	A	26-lb. U.S.	9.4	10.5	+11.7	12.0	14.4	+20.0	99	118	+19.2	93	102	+ 9.7
7, 11	B	26-lb. U.S.	6.8	8.2	+20.6	10.6	12.0	+13.2	62	87	+40.3	65	86	+32.3
8, 12	A	23-lb. European	7.8	10.5	+34.6	10.1	14.1	+39.6	56	87	+37.5	78	102	+30.8
8, 12	B	23-lb. European	6.6	6.8	+ 3.0	9.2	8.8	- 4.3	43	60	+39.5	52	76	+46.2
Composite			7.7	9.0	+16.9	10.5	12.3	+17.1	65	88	+35.4	72	92	+27.8
35.8-lb. Linerboard														
14, 18	A	26-lb. U.S.	10.8	13.8	+27.8	14.3	20.1	+40.6	122	146	+19.7	105	162	+54.3
14, 18	B	26-lb. U.S.	8.5	11.2	+31.8	9.9	14.0	+41.4	76	116	+52.6	75	87	+16.1
13, 17	A	23-lb. European	8.9	11.0	+23.6	12.9	13.4	+ 3.9	91	106	+16.5	105	126	+20.0
13, 17	B	23-lb. European	7.7	8.7	+13.0	11.3	12.4	+ 9.7	68	74	+ 8.8	80	92	+15.0
Composite			9.0	11.2	+24.5	12.1	15.0	+24.0	89	111	+24.7	91	117	+28.6
41.0-lb. Linerboard														
19, 22	A	26-lb. U.S.	13.2	12.7	- 3.8	18.4	18.6	+ 1.1	151	141	- 6.6	154	179	+16.2
19, 22	B	26-lb. U.S.	9.6	10.7	+11.5	13.9	13.1	- 5.8	96	82	-14.6	110	101	- 8.2
20, 21	A	23-lb. European	11.5	10.1	-12.2	13.5	17.3	+28.1	107	116	+ 8.4	97	113	+16.5
20, 21	B	23-lb. European	9.2	8.9	- 3.3	11.9	13.8	-16.0	54	95	+72.2	92	93	+ 1.1
Composite			10.9	10.6	- 2.8	14.4	15.7	+9.0	102	109	+ 6.9	113	122	+ 8.0

[a] E.G. liner used as reference.

TABLE IV

COMPARISON OF BOXES HANDLING PERFORMANCE ON A UNIT WEIGHT BASIS

Run	Flute	Type Medium	Corner Drop, Drops/100-lb Combined Board Weight, 50% R H, E G Liner	50% R H, S C Liner	50% R H, Diff, %[a]	65% R H, E.G Liner	65% R H, S C Liner	65% R H, Diff, %[a]	Drum Performance, falls/100-lb Combined Board Weight, 50% R H, E G Liner	50% R H, S C Liner	50% R H, Diff, %[a]	65% R H, E G Liner	65% R H, S C. Liner	65% R H, Diff, %[a]
25 6-lb Linerboard														
2, 6	A	26-lb. U S	9.5	6.7	-29.5	11.2	11.0	- 1.8	78	77	- 1.3	81	82	+ 1.2
2, 6	B	26-lb U S	6.5	5.3	-18.5	9.6	7.4	-22.9	60	54	-10.0	57	52	- 8.8
1, 5	A	23-lb European	7.3	5.4	-26.0	9.0	7.8	-13.3	48	72	+50.0	57	56	- 1.8
1, 5	B	23-lb European	5.7	4.3	-24.6	8.0	7.6	- 5.0	54	28	-48.1	59	37	-37.3
Composite			7.3	5.5	-24.7	9.5	8.5	-10.5	61	59	- 3.3	64	57	-10.9
30 7-lb. Linerboard														
[illegible] 11	A	26-lb. U S	8.7	9.8	+12.6	10.8	13.1	+21.3	92	110	+19.6	84	93	+10.7
[illegible] 11	B	26-lb. U S	6.5	7.9	+21.5	10.0	11.3	+13.0	59	84	+42.4	61	81	+32.8
[illegible] 12	A	23-lb European	7.5	10.2	+36.0	9.4	13.6	+44.7	54	84	+55.6	73	98	+34.2
[illegible] 12	B	23-lb. European	6.6	6.9	+ 4.5	9.0	8.7	- 3.3	43	61	+41.9	51	75	+47.1
Composite			7.4	8.7	+17.6	9.8	11.7	+19.4	63	85	+34.9	67	87	+29.9
35 8-lb Linerboard														
[illegible] 18	A	26-lb U S	9.1	11.7	+17.6	11.6	16.8	+44.8	103	124	+20.4	85	135	+58.8
[illegible] 18	B	26-lb U S.	7.4	9.8	+32.4	8.5	12.2	+43.5	67	102	+52.2	65	76	+16.9
[illegible] 17	A	23-lb European	7.8	9.7	+24.4	11.0	11.6	+ 5.5	80	94	+17.5	90	109	+21.1
[illegible] 17	B	23-lb European	7.1	8.1	+14.1	10.1	11.4	+12.9	62	69	+11.3	71	84	+18.3
Composite			7.9	9.9	+25.3	10.3	13.0	+26.2	78	98	+25.6	78	101	+29.5
41 0-lb Linerboard														
19, 22	A	26-lb U S	10.3	10.2	- 1.0	14.0	14.4	+28.6	118	114	- 3.4	118	139	+17.8
19, 22	B	26-lb U S	7.9	9.1	+15.2	11.0	10.7	- 2.7	79	69	-12.7	87	82	- 5.7
20, 21	A	23-lb European	9.3	8.4	- 9.7	10.6	14.2	+34.0	90	97	+ 7.8	76	93	+22.4
20, 21	B	23-lb European	7.7	7.7	0.0	9.8	12.0	+22.4	45	82	+82.2	76	81	+ 6.6
Composite			8.9	8.8	- 1.1	11.4	12.8	+12.3	84	91	+ 9.6	89	99	+11.2

[a] E.G liner used as reference

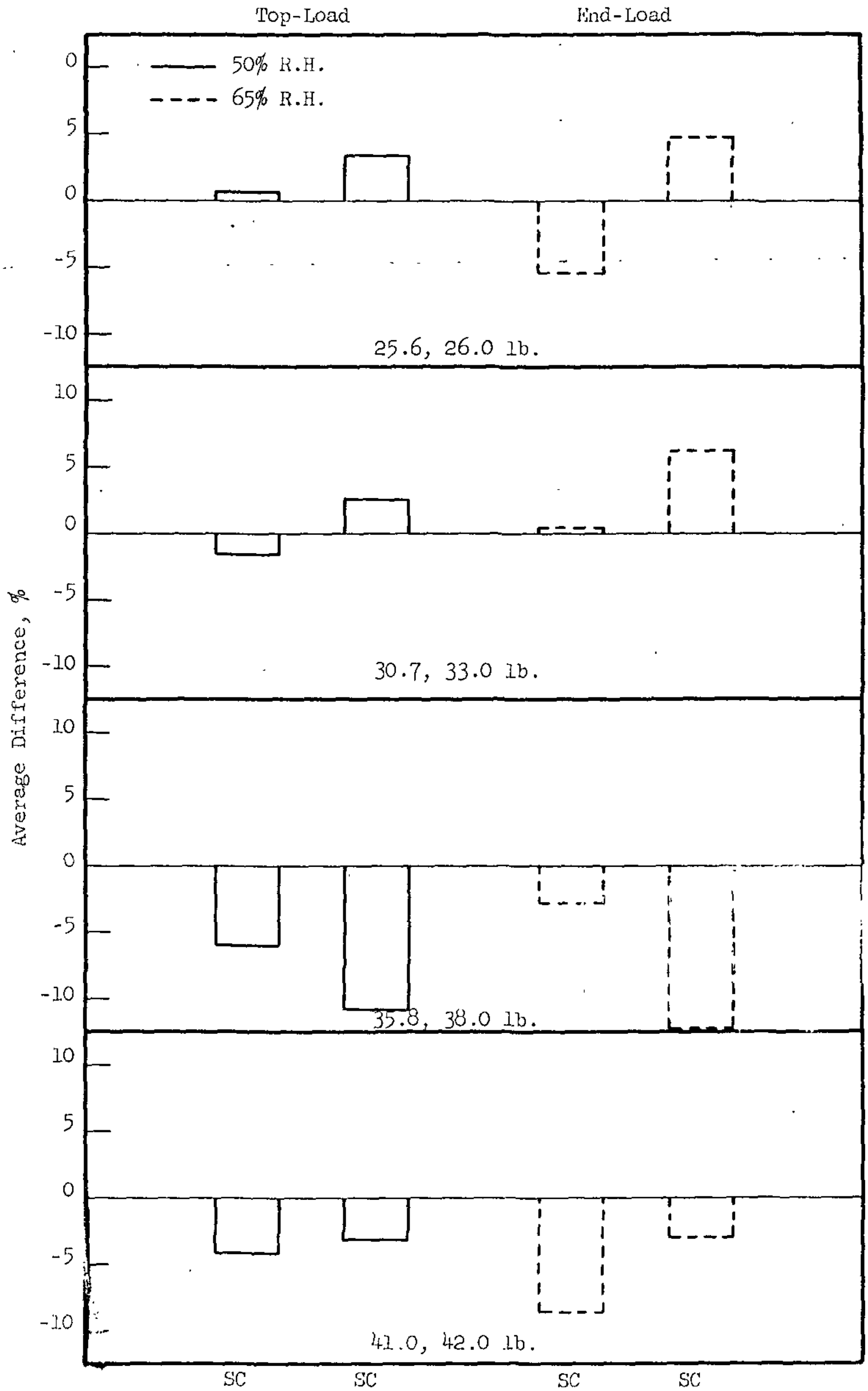


Figure 4a. Comparison of Average Difference in Compression Performance of Boxes Made with European Linerboard (W.G.

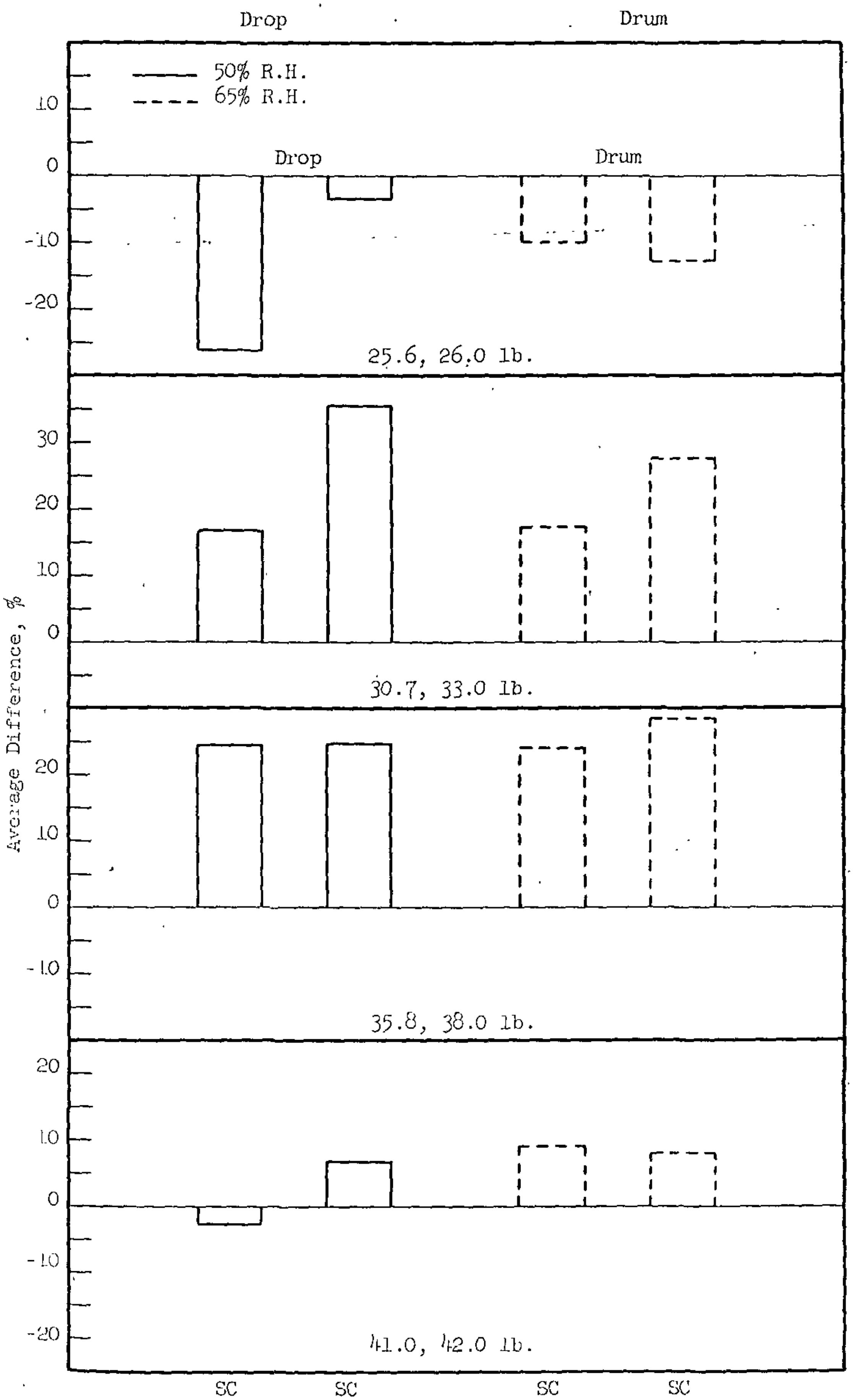


Figure 4b. Comparison of Average Difference in Round Handling

weight and multiplying by 100 to give compression per 100 pounds of combined board weight. The compression results on a unit combined board weight basis are tabulated in Table XIII. Converting the performance results to a unit combined board weight basis improves the relative compression performance of boxes made with Svenska Cellulosa linerboard because, generally, this source manufactures at lower weight levels than Enso Gutseit.

2. Rough Handling Performance

The comparative performance of boxes made with European linerboards in terms of drop and drum results may be seen from the data tabulated in Table XIV and illustrated in Fig. 4b. At the 25.6-lb. grade weight level, the boxes made with Enso Gutseit linerboard exhibit slightly higher drop and drum performance. It is questionable if these differences are significant except for drop performance at 50% R.H. The same general trend is observed when the results are compared on a unit combined board weight basis (see Table XV).

When the rough handling results obtained on boxes made with 30.7-lb. linerboard are considered, it may be seen that the boxes made with Enso Gutseit linerboard exhibited significantly lower drop and drum performance on both a box basis and a unit weight basis. The same trend may be observed for the corresponding results at the 35.8-lb. linerboard grade weight level. At the 41.0-lb. linerboard grade weight level there appears to be no significant difference.

D. Effect of Relative Humidity

As previously mentioned, the evaluations were carried out at both 50 and 65% R.H. because different levels of humidity and temperature are used in the U.S. and Europe as standard conditions. Standard conditions in the U.S. correspond to 50% R.H. at 73°F. whereas in Europe 65% R.H. at 68°F. is standard.

The higher relative humidity and lower temperature of the European standard conditions result in the board being tested at a higher moisture content relative to that associated with the U.S. standard.

Box compression, as the name implies, involves the stiffness characteristics of the combined board (particularly ultimate stiffness) and it is well known that the higher the moisture content of paper or board the lower the ultimate stiffness; consequently, box compression decreases with increase in moisture content. Thus, the lower compression results obtained at 65% R.H. are in keeping with usual experience. The results obtained in this study indicate that the effect of increasing the relative humidity from 50 to 65% R.H. had about the same effect on boxes made with U.S. and European linerboard.

Rough handling as defined herein, has been found to involve a combination of physical properties - fatigue and energy absorption. It is well known that the energy absorption capacity of paper and board increases with moisture content. The observed tendency for rough handling performance to increase with increase in R.H. is, therefore, in accord with expected behavior. Further, the results obtained in this study indicate that the change in R.H. in general had about the same effect on boxes made with U.S. and European linerboard.

E. Comparison of the Physical Properties of Combined Boards Fabricated with U.S. and European Linerboards

The effect of type of linerboard on combined board test properties may be seen from the results tabulated in Tables XVI and XVII, respectively, for [illegible] R.H. It may be noted from the basis weight results tabulated in Tables XVI and XVII and illustrated in Fig. 5 that the combined boards made with U.S. linerboards range from about 2 to 7% higher than the corresponding samples made with European linerboards. For purpose of comparison, the composite average

TABLE XVI

COMBINED BOARD PROPERTIES

(50% Relative Humidity)

			Basis Weight, lb./M sq. ft.					Caliper, pt.					Bursting Strength, p.s.i.					Puncture, unit				
Run	Flute	Type Medium	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]
25.6, 26.0-lb. Linerboard																						
3, 2, 6	A	26-lb. U.S.	102	99	- 2.9	97	- 4.9	191	188	- 1.6	189	- 1.0	148	204	+37.8	232	+103.5	185	180	- 2.7	166	-10.3
3, 2, 6	B	26-lb. U.S.	94	94	0.0	94	0.0	113	111	- 1.8	111	- 1.8	130	168	+29.2	172	+ 32.3	162	160	- 1.2	162	0.0
4, 1, 5	A	23-lb. European	97	94	- 3.1	93	- 4.1	193	188	- 2.6	190	- 1.6	149	204	+36.9	236	+ 58.4	171	160	- 6.4	156	- 3.3
4, 1, 5	B	23-lb. European	91	89	- 2.2	89	- 2.2	112	109	- 2.7	109	- 2.7	135	182	+34.8	196	+ 37.8	154	144	- 6.5	146	- 5.2
Average			96	94	- 2.1	93	- 3.1	152	149	- 2.0	150	- 1.3	140	190	+35.7	207	+ 56.8	168	161	- 4.2	140	-16.7
															(.01)[b]		(.01)			(.01)		(.01)
30.7, 33.0-lb. Linerboard																						
10, 7, 11	A	26-lb. U.S.	114	108	- 5.3	107	- 6.1	193	188	- 2.6	190	- 1.6	218	241	+10.6	232	+ 6.4	200	190	- 5.0	192	- 4.0
10, 7, 11	B	26-lb. U.S.	111	105	- 5.4	104	- 6.3	115	112	- 2.6	114	- 0.9	184	238	+29.3	214	+ 16.3	192	180	- 6.2	175	- 8.9
9, 8, 12	A	23-lb. European	109	104	- 4.6	103	- 5.5	192	190	- 1.0	190	- 1.0	224	264	+17.9	240	+ 7.1	188	179	- 4.8	181	- 3.7
9, 8, 12	B	23-lb. European	106	100	- 5.7	98	- 7.5	112	109	- 2.7	111	- 0.9	206	262	+27.2	232	+ 12.6	173	164	- 5.2	162	- 6.4
Average			110	104	- 5.6	103	- 6.4	153	150	- 2.0	151	- 1.3	208	251	+20.7	230	+ 13.5	188	178	- 5.3	178	- 5.3
															(.01)		(.01)			(.01)		(.01)
35.8, 38.0-lb. Linerboard																						
15, 14, 18	A	26-lb. U.S.	123	119	- 3.3	118	- 4.1	200	196	- 2.0	197	- 1.5	218	298	+36.7	279	+ 28.0	218	206	- 5.5	216	- 0.9
15, 14, 18	B	26-lb. U.S.	119	114	- 4.2	114	- 4.2	117	114	- 2.6	114	- 2.6	190	262	+37.9	262	+ 37.9	197	182	- 7.6	193	- 2.0
16, 13, 17	A	23-lb. European	118	114	- 3.4	113	- 4.2	195	194	- 0.5	194	- 0.5	222	298	+34.2	230	+ 26.1	210	194	- 7.6	200	- 4.8
16, 13, 17	B	23-lb. European	113	109	- 3.5	107	- 5.3	114	113	- 0.9	113	- 0.9	219	282	+28.8	272	+ 24.2	184	178	- 3.3	173	- 6.0
Average			118	114e	- 3.4	113	- 4.2	157	154	- 1.9	155	- 1.3	212	285	+34.4	273	+ 28.8	202	190	- 5.9	196	- 3.0
															(.01)		(.01)			(.01)		(.01)
41, 42-lb. Linerboard																						
23, 19, 22	A	26-lb. U.S.	130	128	- 1.5	124	- 4.6	199	197	- 1.0	200	+ 0.5	240	324	+35.0	297	+ 23.8	232	233	+ 0.4	234	+ 0.9
23, 19, 22	B	26-lb. U.S.	126	122	- 3.2	118	- 6.3	118	117	- 0.8	118	0.0	226	258	+14.2	292	+ 29.2	208	204	- 1.9	200	- 3.8
24, 20, 21	A	23-lb. European	126	123	- 2.4	120	- 4.8	194	196	+ 1.0	196	+ 1.0	287	322	+12.2	338	+ 17.8	220	208	- 5.5	214	- 2.7
24, 20, 21	B	23-lb. European	120	119	- 0.8	116	- 3.3	115	113	- 1.7	116	+ 0.9	235	316	+34.5	310	+ 31.9	196	195	- 0.5	186	- 5.1
Average			126	123	- 2.4	120	- 4.8	156	156	0.0	158	+ 1.3	247	305	+23.4	309	+ 25.1	212	210	- 0.9	209	- 1.4
															(.01)		(.01)			(N.S.)		(NS)

TABLE XVI (Continued)

COMBINED BOARD PROPERTIES

(50% Relative Humidity)

Run	Flute	Type Medium	Geometric Mean Flexural Stiffness, lb.-in.					Flat Crush, p.s.i.					Pin Adhesion, lb./4 sq. in.				
			U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]	U.S. Liner	E.G. Liner	Diff., %[a]	S.C. Liner	Diff., %[a]
							25.6, 26.0-lb. Linerboard										
3, 2, 6	A	26-lb. U. S.	82.6	87.1	+ 5.4	92.6	+12.1	36.2	33.8	- 9.1	36.4	+ 0.6	42	35	-16.7	32	-23.8
3, 2, 6	B	26-lb. U. S.	29.1	33.2	+14.1	32.1	+10.3	54.4	51.4	- 5.5	54.9	+ 0.9	76	62	-18.4	72	- 5.3
4, 1, 5	A	23-lb. European	90.8	93.5	+ 3.0	93.0	+ 2.4	30.8	30.6	- 0.6	30.3	- 1.6	38	33	-13.2	28	-26.3
4, 1, 5	B	23-lb. European	29.8	36.1	+21.1	31.1	+ 4.4	53.2	45.2	-21.8	47.2	-11.3	76	56	-26.3	64	-15.8
Average			58.1	62.5	+ 7.6	62.2	+ 7.1	43.6	40.3	- 7.6	42.2	- 3.2	58	47	-19.0	49	-15.5
							30.7, 33.0-lb. Linerboard										
10, 7, 11	A	26-lb. U. S.	125.1	134.1	+ 7.2	117.5	- 6.1	35.4	37.1	+ 4.8	36.0	+ 1.7	38	30	-21.1	35	- 7.9
10, 7, 11	B	26-lb. U. S.	39.5	46.0	+16.5	38.2	- 3.3	56.1	53.4	+ 4.8	57.3	+ 1.7	36	65	-21.1	65	- 7.9
9, 8, 12	A	23-lb. European	131.4	144.2	+ 9.7	128.1	- 2.5	31.6	32.5	+ 2.8	33.3	+ 5.4	34	28	-17.6	32	- 5.9
9, 8, 12	B	23-lb. European	40.3	42.6	+ 5.7	40.4	+ 0.2	47.2	47.8	+ 1.3	44.1	- 6.6	70	53	-24.3	84	+20.0
Average			84.1	91.7	+ 9.0	81.1	- 3.6	42.6	42.7	+ 0.2	42.7	+ 0.2	57	44	-22.8	54	- 5.3
							35.8, 38.0-lb. Linerboard										
15, 14, 18	A	26-lb. U. S.	118.1	168.6	+42.8	132.5	+12.2	36.0	36.7	+ 1.9	34.7	- 3.6	40	36	-10.0	35	-12.5
15, 14, 18	B	26-lb. U. S.	40.7	53.8	+32.2	43.2	+ 6.1	51.3	51.0	- 0.6	52.4	+ 2.1	52	48	- 7.7	60	+15.4
16, 13, 17	A	23-lb. European	122.6	169.3	+38.1	147.4	+20.2	32.3	32.4	+ 0.3	32.3	0.0	37	32	-13.5	34	- 8.1
16, 13, 17	B	23-lb. European	39.6	52.0	+31.3	45.3	+14.4	46.0	47.3	+ 2.8	44.9	- 2.4	62	50	-19.4	52	-16.1
Average			80.2	110.9	+38.3	92.1	+14.8	41.4	41.9	+ 1.2	41.1	- 0.7	48	42	-12.5	45	- 6.3
							41, 42-lb. Linerboard										
23, 19, 22	A	26-lb. U. S.	142.2	181.9	+27.9	164.6	+15.8	35.4	35.4	0.0	37.6	+ 6.2	44	44	0.0	44	0.0
23, 19, 22	B	26-lb. U. S.	42.3	57.8	+36.6	48.0	+13.5	52.5	52.2	- 0.6	49.9	- 5.0	61	59	- 3.3	63	+ 3.3
24, 20, 21	A	23-lb. European	140.1	203.8	+45.5	166.0	+18.5	34.8	34.7	- 0.3	34.0	- 2.3	44	42	- 4.5	44	0.0
24, 20, 21	B	23-lb. European	42.6	58.0	+36.2	48.0	+12.7	46.8	42.5	- 9.2	46.2	- 1.3	62	56	- 9.7	60	- 3.3
Average			91.8	125.4	+36.6	106.7	+16.2	42.4	41.2	- 0.5	41.9	- 1.2	53	50	- 5.7	53	0.0

a Based on U.S. liner results as reference.

b Value in parenthesis indicates significance level: (.01) means difference is significant at 1% level; (.05) significant at 5% level; (N.S. difference not statistically significant at 1 or 5% level.

TABLE XVI (Continued)

COMBINED BOARD PROPERTIES

(50% Relative Humidity)

Run	Flute	Type Medium	Average Torsion Tear, in -oz: U S Liner	E G Liner	Diff, %[a]	S C Liner	Diff, %[a]	Scoreline Torsion Tear, in -oz: U S Liner	E G Liner	Diff, %[a]	S C Liner	Diff, %[a]	M D Edgewise Compression, lb /in: U S Liner	E G Liner	Diff, %[a]	S C Liner	Diff, %[a]	C D Edgewise Compression, lb /in: U S Liner	E G Liner	Diff, %[a]	S C Liner	Diff, %[a]
								25 6, 26 0-lb Linerboard														
3, 2, 6	A	26-lb U S	215	196	- 8.8	182	-15.3	202	186	- 7.9	172	-14.9	12.8	9.0	-29.7	11.1	-13.3	37.8	35.3	- 6.6	32.8	-13.2
3, 2, 6	B	26-lb U S	185	176	- 4.9	176	- 4.9	177	168	- 5.1	156	-11.9	19.4	18.0	- 7.2	18.9	- 2.6	38.7	36.0	- 7.0	37.8	- 2.3
[illegible] 5	A	23-lb European	186	168	- 9.7	176	- 5.4	162	151	- 6.8	154	- 4.9	9.7	8.3	-14.4	9.8	+ 1.0	39.8	38.8	- 2.5	36.6	- 8.0
1, 5	B	23-lb European	159	145	- 8.8	150	- 5.7	152	135	-11.2	141	- 7.2	16.7	17.4	+ 4.2	19.2	+15.0	38.3	39.9	+ 4.2	40.4	+ 5.5
Average			186	171	- 8.1	171	- 8.1	173	160	- 7.5[b]	136	-21.4	14.7	13.2	-10.2	14.8	+ 0.7	38.7	37.5	- 3.1	36.9	- 4.7
										(.01)		(.01)			(.01)		(N S)			(.01)		(.01)
								30 7, 33 0-lb Linerboard														
10, 7, 11	A	26-lb U S	244	218	-10.7	212	-13.1	204	193	- 5.4	199	- 2.5	14.9	13.6	- 8.7	16.5	+10.7	41.7	38.3	- 8.2	38.7	- 7.2
10, 7, 11	B	26-lb U S	224	196	-12.5	195	-12.9	208	188	- 9.6	203	- 2.4	29.8	24.8	-16.8	27.6	- 7.4	48.0	45.8	- 4.6	44.0	- 8.3
9, 8, 12	A	23-lb European	214	196	- 8.4	196	- 8.4	180	172	- 4.4	180	0.0	13.4	13.8	+ 3.0	15.7	+17.2	44.8	41.4	- 7.6	44.0	- 1.8
9, 8, 12	B	23-lb European	190	178	- 6.3	167	-12.1	181	163	- 9.9	168	- 7.2	28.3	25.2	-11.0	23.0	-18.7	49.9	46.6	- 6.6	43.9	-12.0
Average			218	197	- 9.6	193	-11.5	193	179	- 7.3	188	- 2.6	21.6	19.4	-10.2	20.7	- 4.2	46.1	43.0	- 6.7	42.7	- 7.4
										(.01)		(.01)			(.01)		(.05)			(.01)		(.01)
								35 8, 38 0-lb Linerboard														
15, 14, 18	A	26-lb U S	266	242	- 9.0	227	-14.7	227	218	- 4.0	201	-11.5	16.7	18.1	+ 8.4	17.2	+ 3.0	43.9	43.2	- 1.6	45.2	+ 3.0
15, 14, 18	B	26-lb U S	232	217	- 6.5	230	- 0.9	216	195	- 9.7	226	+ 4.6	31.5	31.8	+ 1.0	28.6	- 9.2	48.3	50.9	+ 5.4	47.0	- 2.7
16, 13, 17	A	23-lb European	246	211	-14.2	218	-11.4	203	181	-10.8	201	- 1.0	18.5	17.1	- 7.6	16.0	-13.5	45.8	46.5	+ 1.5	47.4	+ 3.5
16, 13, 17	B	23-lb European	204	191	- 6.4	198	- 2.9	194	174	-10.3	188	- 3.1	30.5	30.4	- 0.3	28.8	- 5.6	48.8	51.0	+ 4.5	51.7	+ 5.9
Average			237	215	- 9.3	218	- 8.0	210	192	- 8.6	204	- 2.9	24.3	24.4	+ 0.4	22.7	- 6.6	46.7	47.9	+ 2.6	47.8	+ 2.4
										(.01)		(.01)			(N S)		(.01)			(.01)		(.01)
								41, 42-lb Linerboard														
23, 19, 22	A	26-lb U S	280	256	- 8.6	242	-13.6	230	214	- 7.0	204	-11.3	21.2	20.1	- 5.2	23.4	+10.4	47.4	50.1	+ 5.7	47.0	- 0.8
23, 19, 22	B	26-lb U S	258	241	- 6.6	222	-14.0	236	224	- 5.1	206	-12.7	37.0	41.0	+10.8	35.2	- 4.9	49.8	52.4	+ 5.2	46.8	- 6.0
24, 20, 21	A	23-lb European	255	238	- 6.7	216	-15.3	204	204	0.0	185	- 9.3	21.2	22.2	+ 4.7	25.5	+20.3	50.3	52.2	+ 3.8	53.6	+ 6.6
24, 20, 21	B	23-lb European	224	214	- 4.5	204	- 8.9	200	204	+ 2.0	191	- 4.5	31.9	38.0	+19.1	35.4	+11.0	52.6	54.0	+ 2.7	52.3	- 0.6
Average			254	237	- 6.7	221	-13.0	218	212	- 2.8	197	- 9.6	25.3	30.3	+19.8	27.4	+ 8.3	50.0	52.2	+ 4.4	49.9	- 0.2
										(.01)		(.01)			(.01)		(.01)			(.01)		(N S)

TABLE XVII

COMBINED BOARD PROPERTIES
(65% Relative Humidity)

			Basis Weight, lb./M sq. ft.					Caliper, pt.					Bursting Strength, p.s.i.					Puncture, unit				
Run	Flute	Type Medium	U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %	U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %	U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %	U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %
25.6, 26.0-lb Linerboard																						
3, 2, 6	A	26-lb. U. S.	104	101	- 2.9	99	- 4.8	196	183	- 4.1	190	- 3.1	164	228	+39.0	258	+57.3	182	176	- 3.3	170	- 6.6
3, 2, 6	B	26-lb. U. S.	98	96	- 2.0	96	- 2.0	114	111	- 2.6	111	- 2.6	132	184	+39.4	236	+78.8	175	170	- 2.9	170	- 2.9
4, 1, 5	A	23-lb. European	99	96	- 3.0	95	- 4.0	192	190	- 1.1	185	- 3.6	170	202	+18.8	251	+47.6	164	160	- 2.4	158	- 3.7
4, 1, 5	B	23-lb. European	94	91	- 3.2	90	- 4.3	114	110	- 3.5	110	- 3.5	139	237	+70.5	251	+80.6	168	150	-10.7	154	- 8.3
Average			99	96	- 3.3	95	- 4.4	154	150	- 2.7	149	- 3.3	151	213	+41.1	249	+64.9	172	164	- 4.7	163	-10.5
30.7, 33.0-lb. Linerboard																						
10, 7, 11	A	26-lb. U. S.	116	111	- 4.3	110	- 5.2	194	191	- 1.5	195	+ 0.5	239	290	+21.3	246	+ 2.9	196	195	- 0.5	191	- 2.6
10, 7, 11	B	26-lb. U. S.	113	106	- 6.2	106	- 6.2	115	113	- 1.7	114	- 0.9	208	247	+18.8	238	+14.4	208	190	- 8.7	195	- 6.2
9, 8, 12	A	23-lb. European	112	107	- 4.5	104	- 7.1	193	190	- 1.6	194	+ 0.5	250	310	+24.0	258	- 1.5	189	183	- 3.2	176	- 6.9
9, 8, 12	B	23-lb. European	110	102	- 7.3	101	- 8.2	113	112	- 0.9	113	0.0	229	287	+25.3	227	- 0.9	183	176	- 3.8	182	- 0.5
Average			113	107	- 5.3	105	- 7.1	154	152	- 1.3	154	0.0	232	284	+22.4	242	+ 4.3	194	186	- 8.2	186	- 8.2
35.8, 38.0-lb. Linerboard																						
15, 14, 18	A	26-lb. U. S.	126	123	- 2.4	120	- 4.8	198	196	- 1.0	195	- 1.5	242	315	+30.2	320	+32.2	216	214	- 0.9	216	0.0
15, 14, 18	B	26-lb. U. S.	121	116	- 4.1	115	- 5.0	118	116	- 1.7	115	- 2.5	248	295	+19.0	290	+16.9	217	203	- 6.5	206	- 5.1
16, 13, 17	A	23-lb. European	122	117	- 4.1	116	- 4.9	194	195	+ 0.5	195	+ 0.5	242	322	+33.1	336	+38.8	214	200	- 6.5	198	- 7.5
16, 13, 17	B	23-lb. European	115	112	- 2.6	109	- 5.2	115	113	- 1.7	113	- 1.7	251	326	+29.9	320	+27.5	204	192	- 5.9	194	- 4.9
Average			121	117	- 3.3	115	- 5.0	156	155	- 0.6	155	- 0.6	246	290	+17.9	317	+28.9	213	202	- 5.2	204	- 4.2
41, 42-lb. Linerboard																						
23, 19, 22	A	26-lb. U. S.	133	131	- 1.5	129	- 3.0	199	197	- 1.0	198	- 0.5	260	346	+33.1	348	+33.8	238	230	- 3.4	226	- 5.0
23, 19, 22	B	26-lb. U. S.	128	126	- 1.6	123	- 3.9	118	117	- 0.8	118	0.0	254	323	+27.2	334	+31.5	230	228	- 0.9	217	- 5.7
24, 20, 21	A	23-lb. European	128	127	- 0.8	122	- 4.7	198	196	- 1.0	196	- 1.0	284	347	+22.2	376	+32.4	216	226	+ 4.6	209	- 3.2
24, 20, 21	B	23-lb. European	122	121	- 0.8	115	- 5.7	116	115	- 0.9	116	0.0	278	342	+23.0	344	+23.7	211	216	+ 2.4	204	- 3.3
Average			128	126	- 1.6	122	- 4.7	158	156	- 1.3	157	- 0.6	269	340	+26.4	351	+30.5	224	225	+ 0.4	214	- 4.5

TABLE VII (Continued)

COMBINED BOARD PROPERTIES
(65% Relative Humidity)

Run	Flute	Type Medium	Average Torsion Tear, in -oz: U S Liner	E G Liner	Diff, %	S C Liner	Diff, %	Scoreline Torsion Tear, in -oz: U S Liner	E G Liner	Diff, %	S C Liner	Diff, %	M D Edgewise Compression, lb /in: U S Liner	E G Liner	Diff, %	S C Liner	Diff, %	C D Edgewise Compression, lb /in: U S Liner	E G Liner	Diff, %	S C Liner	Diff, %
								25.6, 26.0-lb Linerboard														
3, 2, 6	A	26-lb U S	236	223	-5.5	220	-6.8	223	203	-9.0	194	-13.0	12.2	11.0	-9.8	12.3	+0.8	36.5	34.6	-5.2	33.7	-7.7
3, 2, 6	B	26-lb U S	200	192	-4.0	194	-3.0	190	192	+1.1	178	-6.3	20.7	18.5	-10.6	19.3	-6.8	37.7	34.6	-8.2	36.9	-2.1
4, 1, 5	A	23-lb European	200	178	-11.0	202	+1.0	187	164	-12.3	180	-3.7	11.8	10.2	-13.6	10.9	-7.6	38.9	37.3	-4.1	35.8	-8.0
4, 1, 5	B	23-lb European	182	174	-4.4	168	-7.7	176	163	-7.4	158	-10.2	20.1	17.6	-12.4	19.6	-2.5	38.3	37.0	-3.4	37.9	-1.0
Average			205	192	-6.3	196	-4.4	194	181	-6.7	178	-8.2	16.2	14.3	-11.7	15.5	-4.3	37.9	35.9	-5.3	36.1	-4.7
								30.7, 38.0-lb Linerboard														
10, 7, 11	A	26-lb U S	264	241	-8.7	238	-9.8	234	222	-5.1	223	-4.7	15.8	14.2	-10.1	17.2	+8.9	41.4	40.5	-2.2	38.8	-6.3
10, 7, 11	B	26-lb U S	254	230	-9.4	222	-12.6	244	225	-7.8	223	-8.6	29.0	25.8	-11.0	26.0	-10.3	43.4	44.0	+1.4	41.8	-3.7
9, 8, 12	A	23-lb European	246	216	-12.2	206	-16.3	212	193	-9.0	201	-5.2	14.7	14.0	-4.8	16.5	+12.2	43.6	41.4	-5.0	42.6	-2.3
9, 8, 12	B	23-lb European	226	202	-10.6	196	-13.3	207	192	-7.2	196	-5.3	27.1	22.8	-15.9	23.6	-12.9	45.1	43.7	-3.1	45.0	-0.2
Average			248	222	-10.5	216	-12.9	224	208	-7.1	211	-5.8	21.7	19.2	-11.5	20.8	-4.1	43.4	42.4	-2.3	42.1	-3.0
								35.8, 38.0-lb Linerboard														
15, 14, 18	A	26-lb U S	298	271	-9.1	268	-10.1	260	248	-4.6	247	-5.0	20.7	19.8	-4.3	19.4	-6.3	42.7	43.7	+2.3	42.7	0.0
15, 14, 18	B	26-lb U S	266	232	-12.8	246	-7.5	242	226	-6.6	251	+3.7	32.2	35.0	+8.7	30.6	-4.7	45.1	46.3	+2.7	44.8	-0.7
16, 13, 17	A	23-lb European	274	230	-16.[illegible]	255	-6.9	225	195	-13.3	229	+1.8	19.3	18.0	-6.7	17.4	-9.8	45.6	46.4	+1.8	45.9	+0.7
16, 13, 17	B	23-lb European	236	206	-12.7	228	-3.4	205	202	-1.5	217	+5.9	30.7	32.4	+5.5	28.5	-7.2	44.9	50.8	+13.1	48.1	+7.1
Average			269	235	-12.6	249	-7.4	233	218	-6.4	236	+1.3	25.7	26.3	+2.3	24.0	-6.6	44.6	46.8	+4.9	45.4	+1.8
								41, 42-lb Linerboard														
23, 19, 22	A	26-lb U S	296	280	-5.4	272	-8.1	255	251	-1.6	239	-6.3	23.7	26.5	+11.8	24.0	+1.3	46.9	48.6	+3.6	47.2	+0.6
23, 19, 22	B	26-lb U S	285	253	-11.2	244	-14.4	265	241	-9.1	241	-9.1	36.9	40.0	+8.4	40.1	+8.7	47.1	48.8	+3.6	45.3	-3.8
24, 20, 21	A	23-lb European	282	272	-3.5	246	-12.8	235	238	+1.3	207	-11.9	20.9	24.5	+17.2	25.6	+22.5	50.0	50.9	+1.8	50.5	+1.0
24, 20, 21	B	23-lb European	238	240	+0.8	216	-9.2	222	207	-6.8	212	-4.5	35.3	38.9	+10.2	38.0	+7.6	49.8	50.3	+1.0	48.9	-1.8
Average			275	261	-5.1	245	-10.9	244	234	-4.1	225	-7.8	29.2	32.5	+11.3	31.9	+9.2	48.5	49.7	+2.5	48.0	+1.0

TABLE XVII (Continued)

COMBINED BOARD PROPERTIES
(65% Relative Humidity)

Run	Flute	Type Medium	Geometric Mean Flexural Stiffness, lb.-in. U.S. Liner	E.G. Liner	Diff.,[a] %	S.C. Liner	Diff., %	Flat Crush, p.s.i. U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %	Pin Adhesion, lb./4 sq. in. U.S. Liner	E.G. Liner	Diff., %	S.C. Liner	Diff., %
							25.6, 26.0-lb. Linerboard										
3, 2, 6	A	26-lb. U. S.	81.7	93.5	+14.4	85.1	+ 4.2	33.5	32.6	- 2.7	33.5	0.0	36	35	- 2.8	30	-16.7
3, 2, 6	B	26-lb. U. S.	26.2	30.4	+16.0	29.3	+11.8	56.1	55.8	- 0.5	55.9	- 0.4	79	70	-11.4	62	-21.5
4, 1, 5	A	23-lb. European	84.4	93.9	+11.3	86.7	+ 2.7	30.0	27.6	- 8.0	29.6	- 1.3	30	31	+ 3.3	31	+ 3.3
4, 1, 5	B	23-lb. European	26.8	31.8	+16.4	28.5	+ 6.3	52.2	45.9	-12.1	49.0	- 6.1	70	58	-17.1	50	-28.5
Average			54.8	62.4	+13.9	57.4	+ 4.7	43.0	40.5	- 5.8	40.0	- 7.0	54	49	- 9.3	43	-20.4
							30.7, 33.0-lb. Linerboard										
10, 7, 11	A	26-lb. U. S.	111.4	119.1	+ 6.9	111.9	+ 0.4	32.6	31.6	- 0.3	31.5	- 3.4	27	30	+11.1	32	+18.5
10, 7, 11	B	26-lb. U. S.	35.5	38.3	+ 7.9	34.7	- 2.3	53.4	55.2	+ 3.4	53.6	+ 0.4	75	69	- 8.0	68	- 9.3
9, 8, 12	A	23-lb. European	110.7	128.4	+16.0	107.5	- 2.9	28.7	30.1	+ 4.9	30.5	+ 6.3	31	25	-19.4	30	- 3.3
9, 8, 12	B	23-lb. European	36.0	39.0	+ 8.3	34.7	- 3.6	48.5	49.6	+ 2.3	51.9	+ 7.0	77	57	-26.0	60	-22.1
Average			73.4	81.2	+10.6	72.2	- 1.6	40.8	41.6	+ 2.0	41.9	+ 2.7	53	45	-15.1	48	-15.1
							35.8, 38.0-lb. Linerboard										
15, 14, 18	A	26-lb. U. S.	109.6	149.3	+36.2	116.8	+ 6.6	32.6	30.3	- 7.1	33.3	+ 2.1	34	31	- 8.8	31	- 8.8
15, 14, 18	B	26-lb. U. S.	37.2	49.8	+33.9	39.2	+ 5.4	55.6	54.3	- 2.3	51.4	- 2.3	56	46	-17.9	60	+ 7.1
16, 13, 17	A	23-lb. European	110.3	147.6	+33.8	125.6	+13.9	29.7	30.9	+ 4.0	30.8	+ 3.7	35	30	-14.3	31	-11.4
16, 13, 17	B	23-lb. European	37.4	48.9	+30.7	41.3	+10.4	53.4	48.7	- 8.8	53.5	+ 0.2	58	68	+17.2	50	-13.8
Average			73.6	98.9	+34.4	80.7	+ 9.6	42.8	41.0	- 4.2	42.3	- 1.2	46	44	- 4.3	43	- 6.5
							41, 42-lb. Linerboard										
23, 19, 22	A	26-lb. U. S.	122.3	163.7	+33.9	137.8	+12.7	31.2	32.0	+ 2.6	32.9	+ 5.4	38	38	0.0	38	0.0
23, 19, 22	B	26-lb. U. S.	41.0	53.9	+31.5	48.1	+17.3	56.2	55.4	- 1.4	52.9	- 5.9	70	46	-34.3	55	-21.4
24, 20, 21	A	23-lb. European	123.8	160.5	+29.6	135.4	+ 9.4	30.4	30.9	+ 1.6	31.8	+ 4.6	37	36	- 2.7	38	+ 2.7
24, 20, 21	B	23-lb. European	39.6	56.4	+42.4	44.1	+11.4	51.3	51.9	+ 1.2	52.7	+ 2.7	57	52	- 8.8	63	+10.5
Average			81.7	108.6	+32.9	91.3	+11.8	42.3	42.7	+ 0.9	42.6	+ 0.7	51	43	-15.7	49	- 3.9

[a] Based on U. S. liner results as reference.

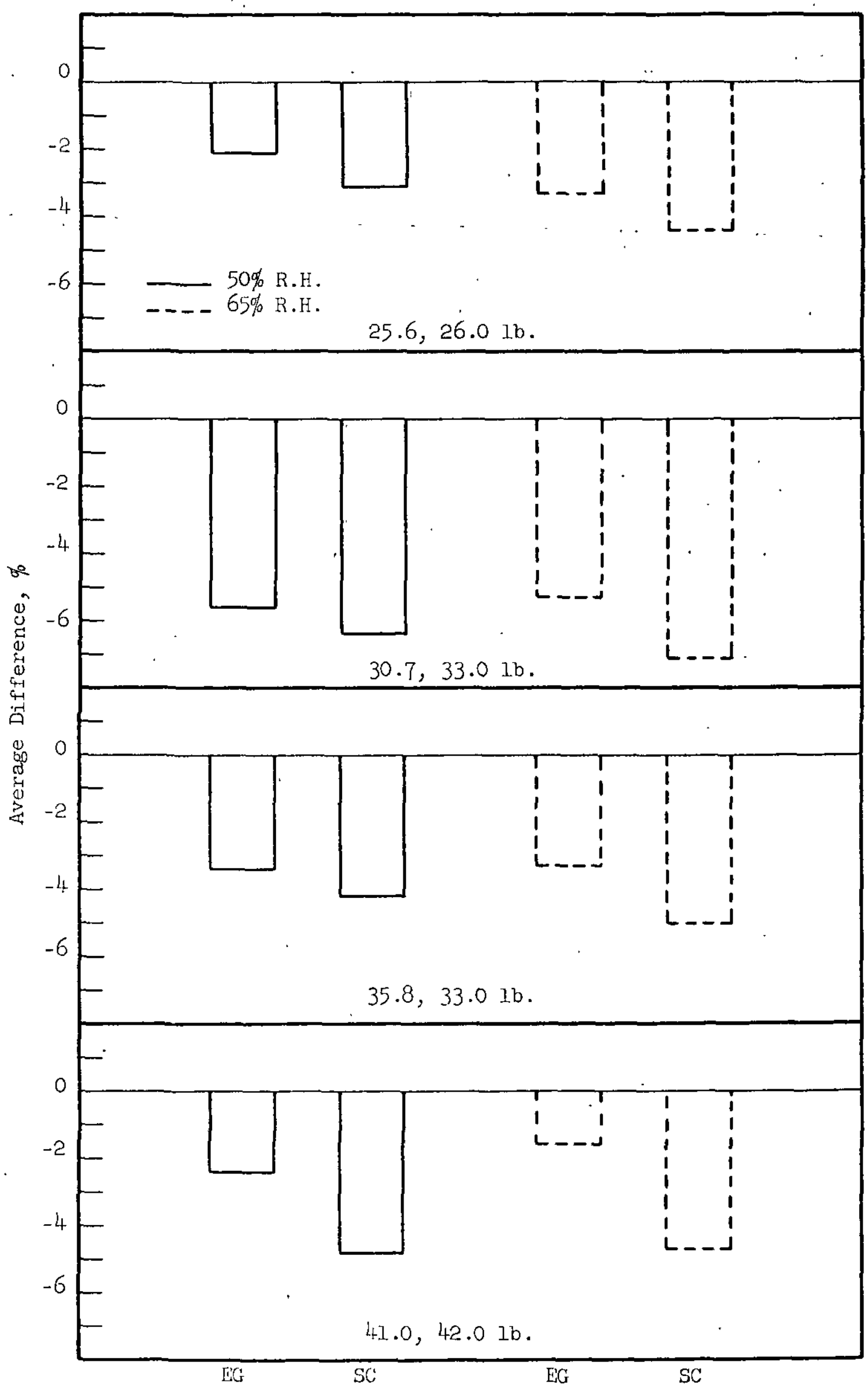


Figure 5. Effect of Type of Linerboard on Combined Board Weight

differences in basis weight are tabulated in Table XVIII together with the corresponding basis weight results on the respective linerboards. It may be seen that at 50% R.H., the basis weight of the combined boards made with European linerboards differ less from the weight of the combined boards made with U.S. linerboards than do the linerboards themselves. The observed differences in linerboard weight, it may be further noted, are considerably greater than the differences calculated on the basis of nominal grade weights.

TABLE XVIII

COMPARISON OF AVERAGE DIFFERENCE IN COMBINED BOARD AND LINERBOARD WEIGHT

U.S. Nominal Grade Weight	Combined Board Difference, %[a] E.G.	Combined Board Difference, %[a] S.C.	Linerboard Difference, %[a] Observed E.G.	Linerboard Difference, %[a] Observed S.C.	Linerboard Difference, %[a] Nominal
50% Relative Humidity					
26.0	-2.1	-3.1	-5.4	-4.6	-1.5
33.0	-5.6	-6.4	-9.1	-11.4	-7.0
38.0	-3.4	-4.2	-5.1	-7.6	-5.8
42.0	-2.4	-4.8	-2.8	-7.5	-2.4
65% Relative Humidity					
26.0	-3.3	-4.4	-2.8	-4.3	--
33.0	-5.3	-7.1	-9.2	-11.8	--
38.0	-3.3	-5.0	-4.5	-6.2	--
42.0	-1.6	-4.7	-3.0	-8.5	--

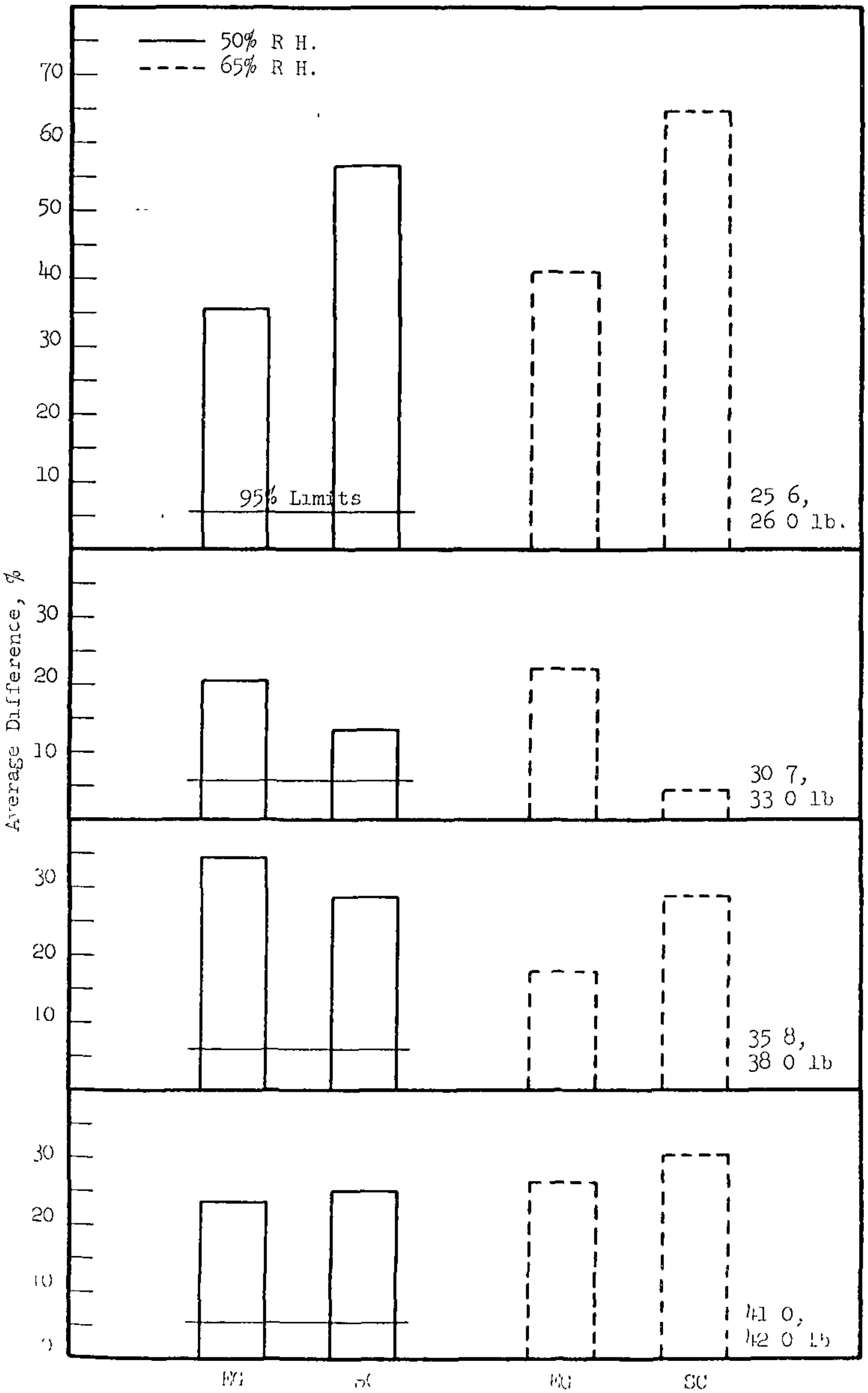
[a]U.S. combined board and linerboard used as reference in calculating percentage differences.

As may be noted from Table XVIII, the Svenska Cellulosa linerboards were made to a lower basis weight than the Enso Gutseit linerboards; hence, the combined boards in general reflect this difference.

As mentioned previously, one of the characteristic differences between U.S. and European linerboard is the bursting strength level at which the respective linerboards are marketed. It may be seen from the bursting strength results tabulated in Tables XVI and XVII and graphed in Fig. 6 that, as would be expected, the combined boards made with European linerboards averaged 25 to 30% higher, at a 2 to 7% lower combined board weight, than the corresponding samples fabricated with U.S. linerboards. The greatest difference is at the lowest grade weight level - 25.6, 26.0-lb. For purpose of comparison, the composite average differences in bursting strength at each level of linerboard weight are retabulated below. The bursting strength results at each level of linerboard weight at 50% R.H. have been statistically analyzed (analysis of variance method) to determine if the observed differences are "real" - i.e., statistically significant. The values in parentheses in the following tabulation indicate the level at which the difference is significant; NS denotes that the difference is not significant at the 5% confidence level.

U.S. nominal Grade Weight	Composite Average Difference[a] in Bursting Strength, %			
	50% R.H.		65% R.H.	
	E.G.	S.C.	E.G.	S.C.
26.0	+35.7(.01)	+56.8(.01)	+41.1	+64.9
33.0	+20.7(.01)	+13.5(.01)	+22.4	+4.3
38.0	+34.4(.01)	+28.8(.01)	+17.9	+28.9
42.0	+23.4(.01)	+25.1(.01)	+26.4	+30.5

[a]Combined board made with U.S. linerboard used as reference.


50% R H.
65% R H.
Average Difference, %
95% Limits
25 6,
26 0 lb.
30 7,
33 0 lb
35 8,
38 0 lb
41 0,
42 0 lb
SC

As would be expected, all the composite average differences at 50% R.H. are statistically significant at the 1% confidence level. Because of the lower weight of the combined boards made with European linerboards, the differences would be even greater on a unit weight basis than obtained on an observed or "as is" basis.

The philosophy practiced in the manufacture of Scandinavian kraft linerboard implies that bursting strength of the linerboard is related to box performance. With reference to this implication, it may be recalled that boxes made with European linerboard exhibited lower top-load compression, about equal end-load compression, and about equal drop and drum performance at the 25 6, 26.0-lb. linerboard grade weight level when compared with boxes made with U.S. linerboard; however, the bursting strength of the combined boards made with European linerboard averaged 35 to 65% higher than that of the corresponding combined board made with U.S. linerboard Further, at the 30.7, 33.0-lb. grade weight level, box performance was about the same for all three "types" of boxes, although the combined boards made with European linerboard exhibited 4 to 22% higher bursting strength. At the two highest grade weight levels (35 8, 38.0-lb and 41 0, 42.0-lb.), the boxes made with Enso Gutseit linerboard exhibited higher top-load compression, slightly higher end-load compression, and about equal rough handling in relation to boxes made with U.S. linerboard, whereas boxes made with Svenska Cellulosa linerboard exhibited slightly lower top- and end-load compression, and about equal rough handling performance when compared with boxes made with U.S. linerboard. However, the bursting strengths of the combined boards made with European linerboards surpassed that of combined board made with U.S. linerboard by about 18 to 35%. Thus, bursting strength of combined board does not appear to be an appropriate criterion on which to base box performance.

The puncture test is used to measure the energy to rupture the board under a specified condition. As such it is an integrating type of test - it measures the work to bend; to initiate puncture of the board; to continue the tear along a line corresponding to the loading edges of the puncture point, etc. Because of this integrating feature, minute weak spots in the test area would be expected to adversely influence the total work to rupture only in direct proportion to their area. In contrast, the bursting strength test, which is a maximum force indicating type of test, is markedly affected by minute weak spots in the test area - e.g., pinholes. Studies (3, 6-8) have shown that the puncture characteristics of combined board are better related to box performance than bursting strength.

The puncture results obtained in this study at 50 and 65% R.H. are given in Tables XVI and XVII. It may be seen from the results in the above tables, which are graphed in Fig. 7, that for practically all combinations the combined board made with U.S. linerboards exhibited slightly higher puncture values than the corresponding boards made with European linerboards. The puncture results at 50% R.H. have been statistically analyzed; the composite average differences and the statistical significance of the differences are given as follows for each grade weight level.

U.S. Nominal Grade Weight	Composite Average Difference[a] Puncture, % 50% R.H. E.G.	S.C.	65% R.H. E.G.	S.C.
26.0	-4.2(.01)	-16.7(.01)	-4.7	-10.5
33.0	-5.3(.01)	-5.3(.01)	-8.2	-8.2
38.0	-5.9(.01)	-3.0(.01)	-5.2	-4.2
42.0	-0.9(NS)	-1.4(NS)	+0.4	-4.5

[a]Combined board made with U.S. linerboard used as reference. Prefix + and - indicates whether higher or lower than U.S. combined board, respectively.

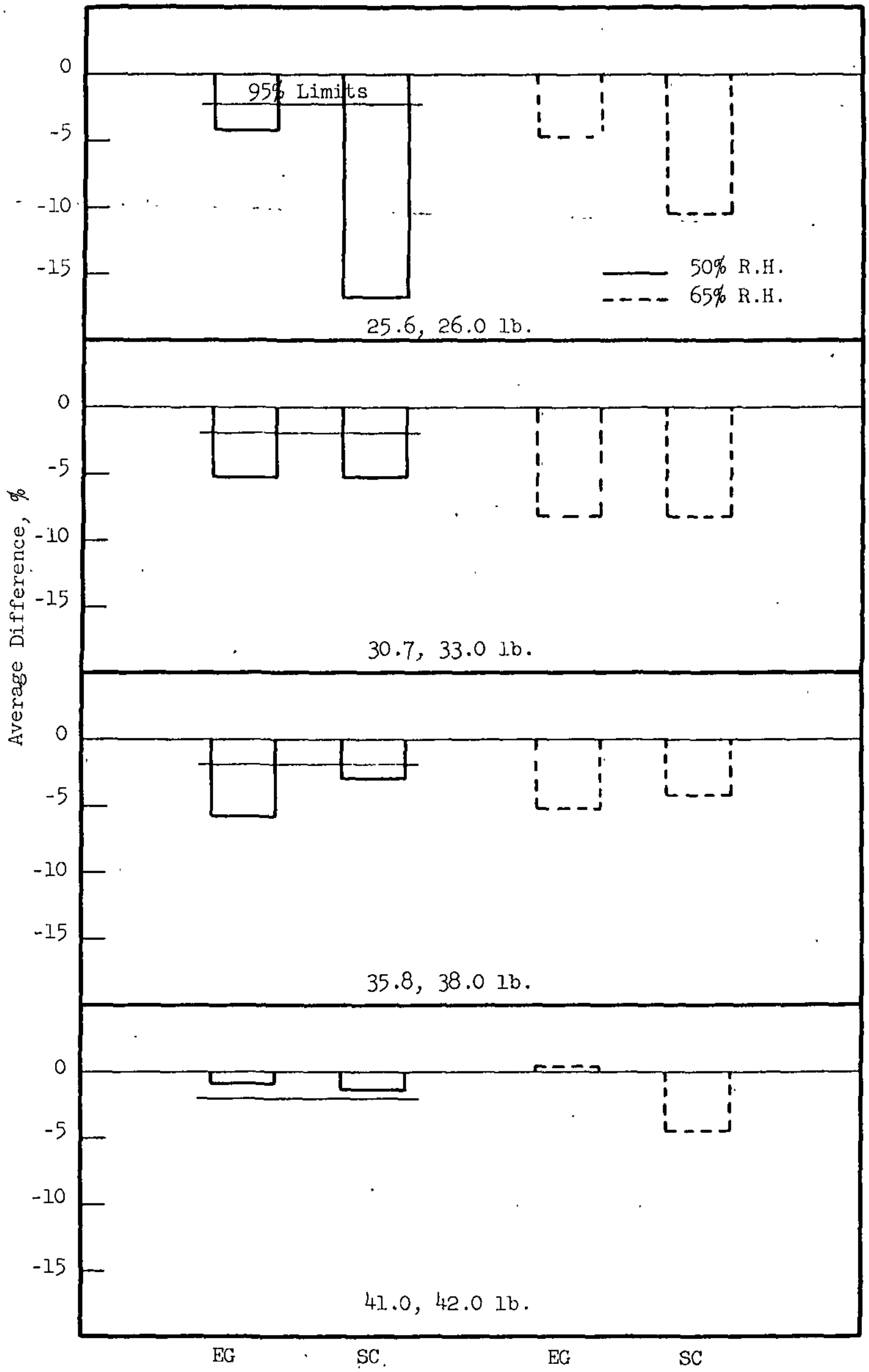


Figure 7. Effect of Type of Linerboard on Combined Board Puncture Resistance

As noted above, the puncture characteristics of combined board made with U.S. linerboard are higher than those of combined board made with European linerboards except for one: the Enso Gutseit board at the 41.0, 42.0-lb. grade weight level at 65% R.H. The composite average differences observed at 50% R.H. are statistically significant at the 1% confidence level except for the results at the 41.0, 42.0-lb. grade weight level. Although the puncture results average 4 to 5% higher for combined boards made with U.S. linerboard, this difference is not reflected in the box compression performance except at the 25.6, 26.0-lb. grade weight level, at which boxes made with U.S. linerboards exhibited higher top-load compression. Because of the lower weights associated with combined boards made with European linerboards, the differences in puncture are about equal in many instances to the difference in combined board weight. Thus, on a unit weight basis the differences in puncture results would not be expected to be significant.

The torsion tear test is a strength test which was developed at The Institute of Paper Chemistry for the purpose of evaluating the tearing strength of corrugated board because it was felt that this physical property was intimately related to rough handling performance of boxes as measured by means of drop and drum tests. By way of validation, it has been found (9, 10) that torsion tear tests on corrugated board are reasonably well related to rough handling performance of boxes. Torsion tear tests on the flap scoreline have been found (9) to give slightly better correlations with rough handling performance than tests on unscored specimens of the combined board.

In the present study, torsion tear tests were made in each principal direction on unscored portions of the board and also in the area of the flap scoreline. The results are tabulated in Tables XVI and XVII, respectively, for 50 and 65% R.H. The results on the unscored portions of combined board are expressed as "average torsion tear" which is the average of the in-machine and cross-machine results It may be seen from the results tabulated in Tables XVI and XVII that in practically all instances the combined board made with U.S. linerboard exhibited higher average torsion tear than the corresponding combined boards made with European linerboards. The composite average differences in average torsion tear at each grade weight level of linerboard weight are retabulated as shown and are graphically illustrated in Fig. 8.

U.S. Nominal Grade Weight	Composite Average Difference in Average Torsion Tear, %[a] 50% R.H. E.G.	50% R.H. S.C.	65% R.H. E.G.	65% R.H. S.C.
26.0	-8.1	-8.1	-6.3	-4.4
33.0	-9.6	-11.5	-10.5	-12.9
38.0	-9.3	-8.0	-12.6	-7.4
42.0	-6.7	-13.0	-5.1	-10.9

[a] Combined board made with U.S. linerboard used as reference.

It may be seen that, in general, the combined boards made with U.S. linerboards are about 5 to 12% higher in torsion tear strength than combined boards made with European linerboards. It is believed that the superiority of U.S. combined board in this characteristic is due to the higher tearing strength of the U.S. linerboards. When rough handling performance is considered, it may be noted that the drop and drum tests do not reflect the difference in torsion tear. A possible explanation for this lack of correlation may be the fact that the torsion tear of combined board reflects to a large extent the tearing strength of the linerboards and it will be seen that the U.S. linerboards are superior to the European linerboards in tearing strength However, from a material standpoint, drop and drum performance is believed to be dependent to a large extent

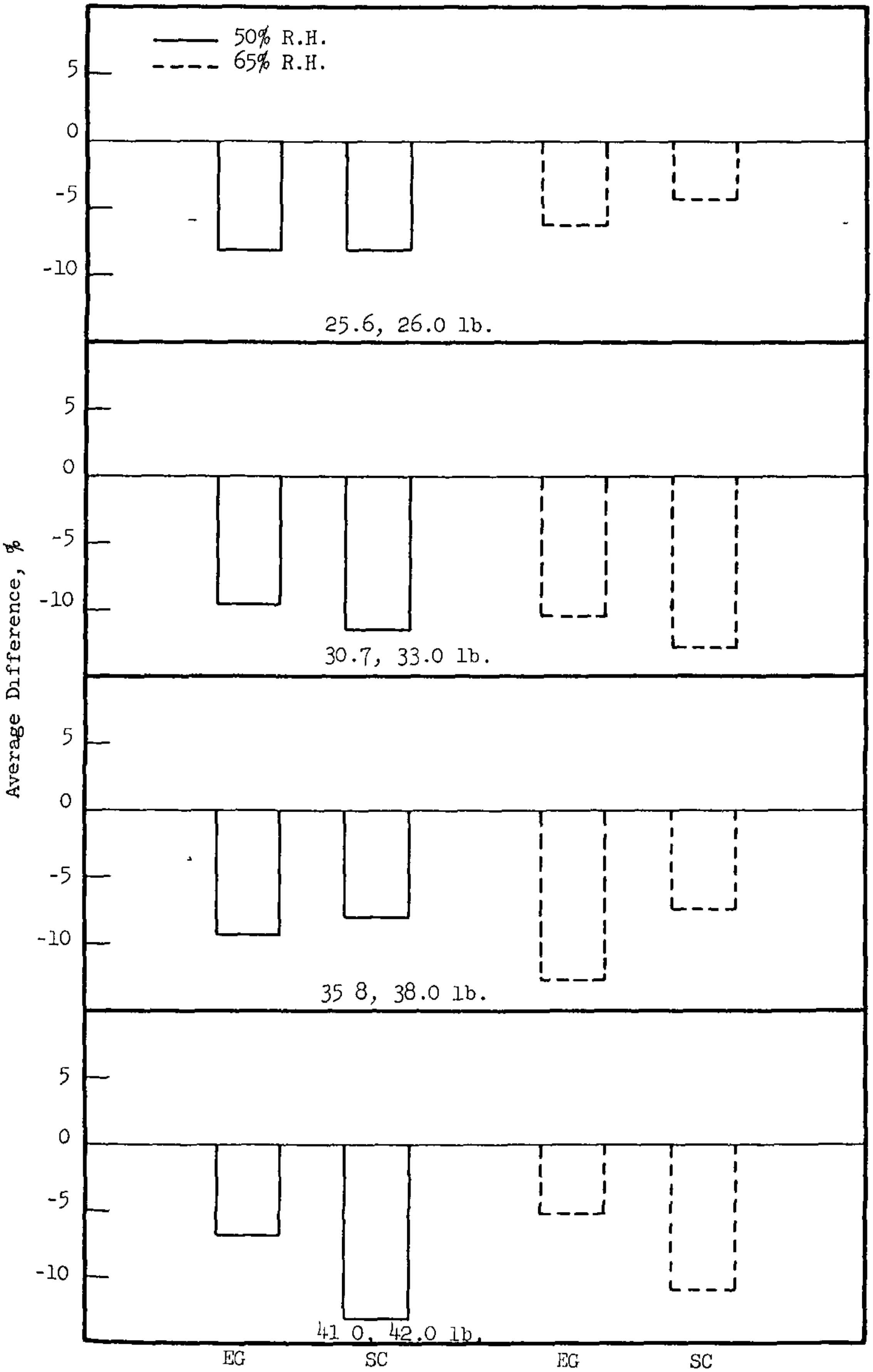


Figure 8 Effect of Type of Linerboard on Combined Board Torsion
[illegible]

on cross-machine tensile strength as well as on tearing strength of the linerboards. As will be shown later, the cross-machine tensile strengths of the European linerboards are markedly higher than the corresponding results on U.S. linerboards

When the scoreline torsion tear results are considered, it may be noted, as in the case of the torsion tear on the unscored boards, that the results on the combined boards made with U.S. linerboards were in most instances higher than the results on the corresponding boards made with European linerboards. The scoreline torsion tear results have been analyzed statistically and the composite average differences together with the observed level of significance are given as follows and graphically illustrated in Fig. 9:

U.S. Nominal Grade Weight, lb.	Composite Average Difference in Scoreline Torsion Tear, %[a]			
	50% R.H.		65% R.H.	
	E.G.	S.C.	E.G.	S.C.
26.0	-7.5(.01)	-21.4(.01)	-6.7	-8.2
33 0	-7.3(.01)	-2.6(.01)	-7.1	-5.8
38.0	-8.6(.01)	-2.9(.01)	-6.4	+1.3
42 0	-2.8(.01)	-9.6(.01)	-4.1	-7.8

[a]Combined board made with U.S. linerboard used as reference.

It may be noted that all the composite average differences are statistically significant at the 1% confidence level indicating that the combined boards made with U.S. linerboards definitely have higher scoreline torsion tear strength. It is believed that this superiority in scoreline torsion tear strength is not reflected in better drop and drum performance for the reason described earlier — i.e., the belief that drop and drum performance is dependent to a large extent on cross-machine tensile strength as well as on tearing strength of linerboard

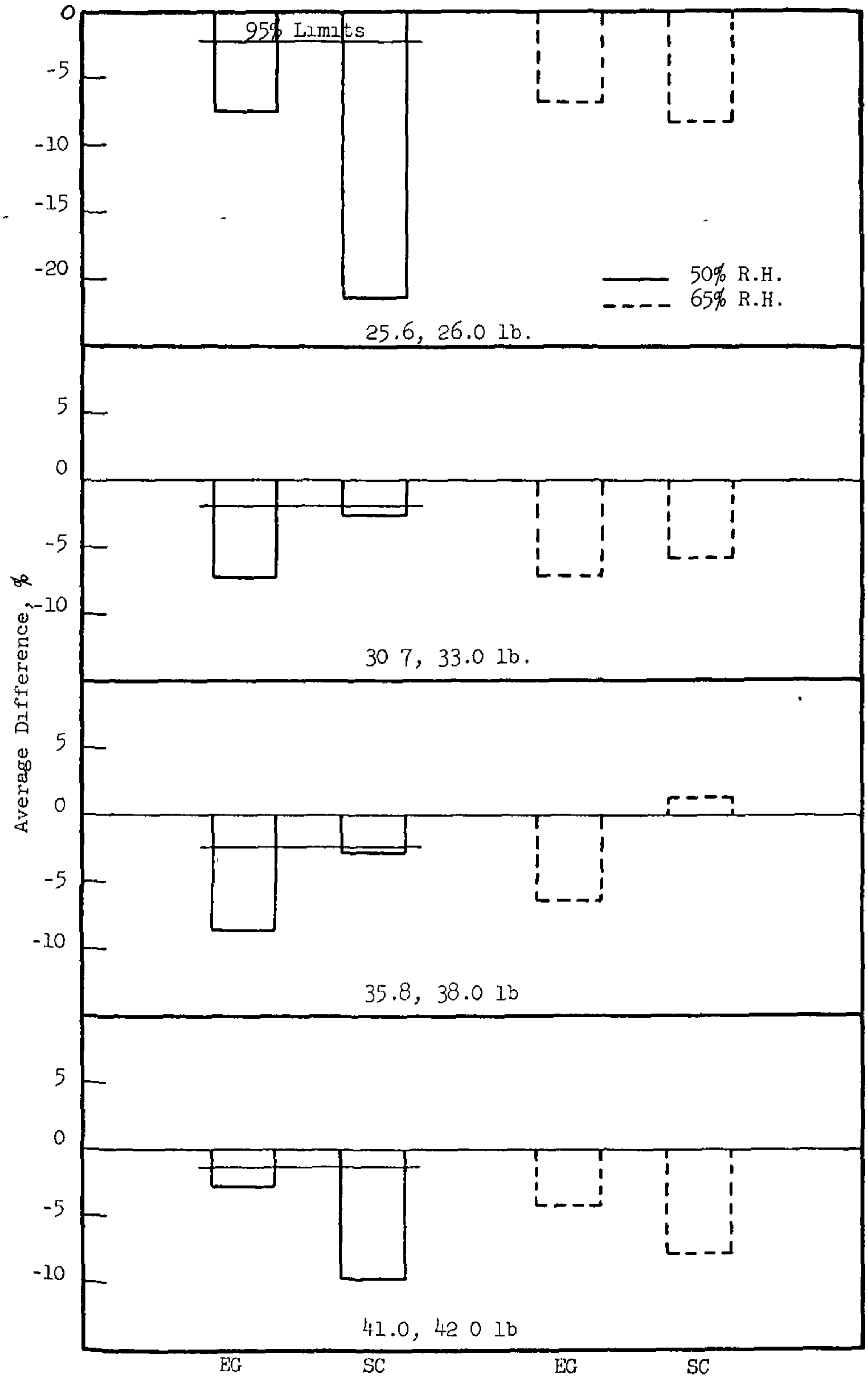


Figure 9 Effect of Type of Linerboard on Combined Board Scoreline [illegible]

Earlier studies (11-13) have shown that top-load box compression may be predicted with reasonable accuracy from a consideration of two basic combined board properties and the load perimeter (2L + 2W) of the box according to the relationship given by Equation (1):

$$P = 2.028\, P_m^{0.746} \left(\sqrt{D_x D_y}\right)^{0.254} Z^{0.492} \qquad (1)$$

when

$$d/Z \geq 1/7$$

where

P = top-load box compression, lb.

P_m = combined board cross-machine edgewise compression, lb./in.

D_x, D_y = combined board flexural stiffness in each principal direction, lb.-in.

Z = load perimeter (2L + 2W), inches

d = depth of box, inches

Studies currently in progress reveal that somewhat the same type of relationship appears to hold for end-load box compression. However, in the case of end-load compression a gap factor, 1 + W/L, should be considered and the combined board edgewise compression of concern is in the machine-direction in contrast to cross direction for top-load compression. Thus, it may be seen that combined board edgewise compression and flexural stiffness have a marked influence on box compression.

A comparison of the machine-direction edgewise compression results tabulated in Tables XVI and XVII for 50 and 65% R.H., respectively, indicates that the machine-direction edgewise compression strength of combined board made with U.S. linerboards was generally higher at the 25.6, 26.0-lb. and the 30.7, 33.0-lb. linerboard grade weight levels but lower at the other two grade weight levels than combined board made with Enso Gutseit linerboard The corresponding comparison for combined boards made with Svenska Cellulosa linerboards indicates a similar but weaker trend As noted earlier, machine-direction edgewise compression is the basic property of combined board of major importance to end-load box compression. In order to compare the combined board and box relationship, the composite average differences in machine-direction edgewise compression strength of the combined boards are given together with the indicated degree of significance and the corresponding end-load box compression results. The composite average differences in edgewise compression are illustrated in Fig. 10.

U.S. Nominal Grade Weight, lb.	Composite Average Difference[a] M.D. Edgewise Compression, %		Composite Average Difference[a] End-Load Box Compression, %	
	E.G.	S.C.	E.G	S.C.
		50% R.H.		
26.0	-10.2(.01)	+0.7(NS)	-4.1(NS)	-0.7(NS)
33.0	-10.2(.01)	-4.2(.05)	-5.3(.01)	-2.8(NS)
38.0	+0.4(NS)	-6.6(.01)	+2.2(NS)	-8.9(.01)
42.0	+19.8(.01)	+8.3(.01)	+7.1(.01)	+5.8(NS)
		65% R.H		
26.0	-11.7	-4.3	-4.2(NS)	+0.4(NS)
33.0	-11.5	-4.1	-6.6(.01)	-0.8(NS)
38.0	+2.3	-6.6	+5.9(.01)	-7.1(.01)
42.0	+11.3	+9.2	+4.4(NS)	+1.2(NS)

[a] Combined board made with U.S. linerboard used as reference

It may be seen from the results tabulated above that for the two lower grade weight levels the composite average differences in machine-direction edgewise compression strength of combined board made with U.S. and Enso Gutseit

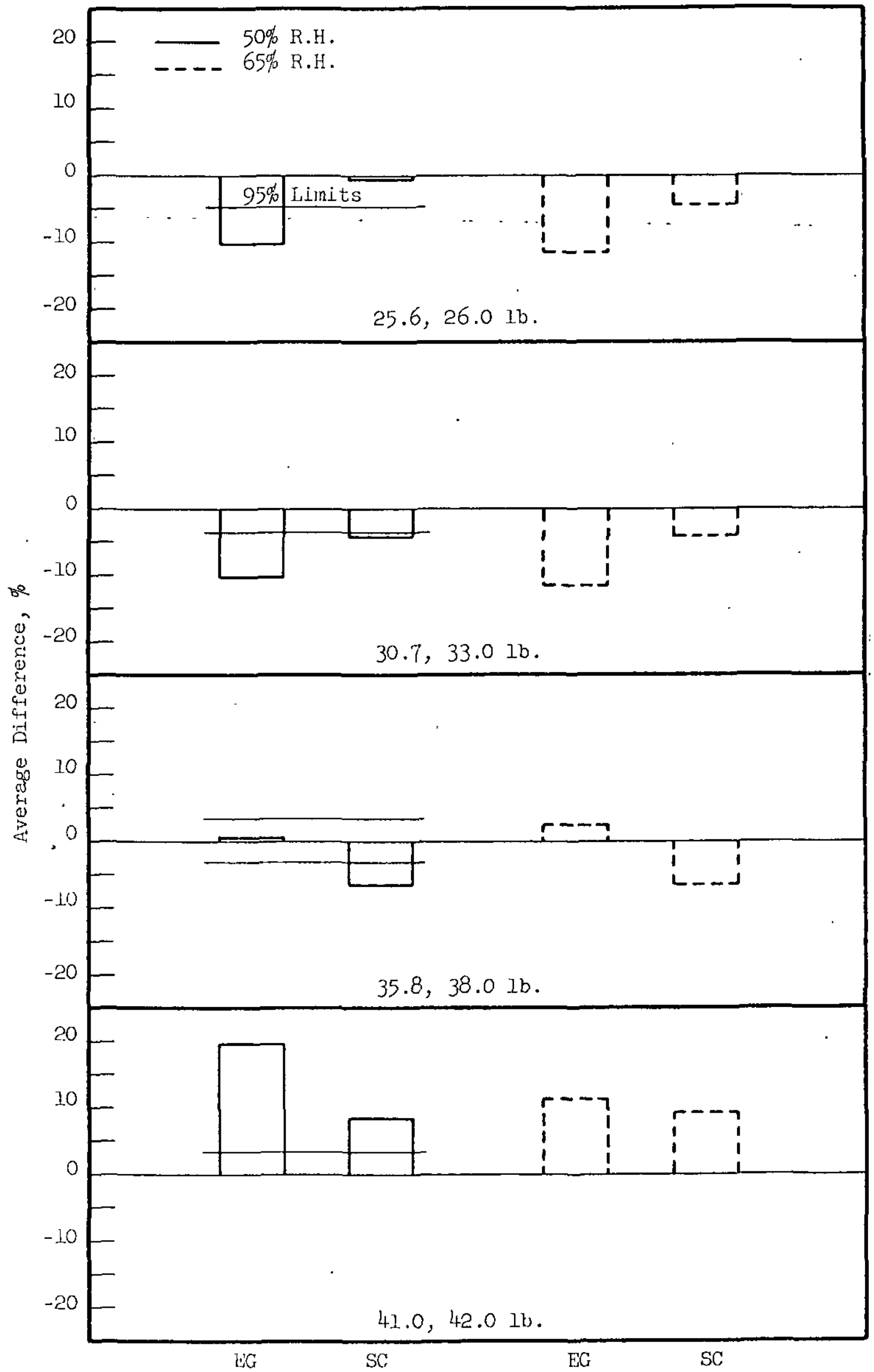


Figure 10. Effect of Type of Linerboard on Combined Board Machine

linerboards are significant at the 1% level; not significant at the 35.7, 38.0-lb. weight level, but significant at the 41.0, 42.0-lb. linerboard weight level. When these results are compared with the corresponding results for end-load box performance it may be seen that there is reasonable agreement. The composite average differences between the results on combined boards made with U.S. and Svenska Cellulosa linerboards show that at the 25.6, 26.0-lb. grade weight level the difference is not significant. At the 30.7, 33.0-lb. and 35.8, 38.0-lb. grade weight levels, the differences favor the U.S. combined boards and are significant at the 5 and 1% confidence levels, respectively. At the 41.0, 42.0-lb. grade weight level the difference is significant and favors the Svenska Cellulosa combined board. When the composite average differences in machine-direction edgewise compression between U.S. and Svenska Cellulosa combined boards are compared with the corresponding results for end-load box compression, it may be noted that there is reasonable agreement.

It may be noted that the results at 65% R.H. are generally slightly higher than the corresponding results at 50% R.H. This trend may appear at first to be an anomaly; however, it should be emphasized that machine-direction edgewise compression specimens fail due to the interflute buckling of the linerboard; thus, the machine-direction flexural stiffness of the linerboards governs failure in machine-direction edgewise compression testing of corrugated board. Flexural stiffness of the linerboard is, in turn, a function of the modulus of elasticity, E, and the moment of inertia, I. The modulus is a strength property of the material, whereas the moment of inertia is a dimensional property of the material. The modulus of elasticity of the linerboard decreases slightly as the relative humidity increases because of a reduction in bonding strength, etc., whereas the moment of inertia, which is a function of the caliper cubed in the case of linerboard — rectangular cross section — increases because the caliper of the linerboard increases at the higher humidity. The net result is that the decrease in E is more than offset by the increase in I; thus, flexural stiffness, EI, of the linerboard increases slightly with relative humidity. This increase in linerboard EI manifests itself as an increase in machine-direction edgewise compression of corrugated board.

As mentioned earlier, studies carried out at The Institute of Paper Chemistry (11-13) have shown that top-load box compression is dependent on two fundamental material properties of the combined board — cross-machine edgewise compression and flexural stiffness — and the load perimeter as indicated by Equation (1). Further, it may be observed from the magnitude of the exponents associated with the edgewise compression, P_m, and the geometric mean of the flexural stiffnesses that the cross-machine edgewise compression strength of the combined board has about twice the importance that the flexural stiffness has on top-load box compression.

The cross-machine edgewise compression results obtained at 50 and 65% R.H. are tabulated in Tables XVI and XVII, respectively. It may be noted that at the 25.6, 26.0-lb. grade weight level the cross-machine edgewise compression strength of the combined board made with U.S. linerboard is higher than that of boards made with European linerboards. The same trend is observed at the 30.7, 33.0-lb. grade weight level. At the 35.8, 38.0-lb. and 41.0, 42.0-lb. grade weight levels the cross-machine edgewise compression strength of the U.S. combined boards are lower than those of the corresponding Enso Gutseit combined boards. In the case of the Svenska Cellulosa combined boards the trend is for the results to be approximately equal to the results obtained on U.S. combined boards. For the purpose of comparing the significance of these noted differences with the top-load box compression results, the composite average differences in cross-machine edgewise compression are shown in the following tabulation; the average differences in cross-machine edgewise compression are illustrated in Fig. 11:

U.S. Nominal Grade Weight, lb.	Composite Average Difference[a] C.D. Edgewise Compression, % E.G.	S.C.	Composite Average Difference[a] Top-Load Box Compression, % E.G.	S.C.
		50% R.H.		
26.0	-3.1(.01)	-4.7(.01)	-5.3(.01)	-5.1(.01)
33.0	-6.7(.01)	-7.4(.01)	+1.6(.01)	0.0(NS)
38.0	+2.6(.01)	+2.4(.01)	+7.4(.01)	+1.0(NS)
42.0	+4.4(.01)	-0.2(NS)	+8.7(.01)	+2.7(.01)
		65% R.H.		
26.0	-5.3	-4.7	-2.1(NS)	-7.5(.01)
33.0	-2.3	-3.0	-1.0(NS)	-0.6(NS)
38.0	+4.9	+1.8	+7.1(.01)	+4.1(.01)
42.0	+2.5	+1.0	+11.2(.01)	+1.6(NS)

[a] Combined board made with U.S. linerboard used as reference.

It may be observed that all the differences between U.S. and Enso Gutseit combined boards are significant at the 1% level of confidence. In the case of the U.S. and Svenska Cellulosa combined boards, all the differences are statistically significant except for the difference at the 41.0, 42.0-lb. grade weight level. Comparison of the combined board edgewise compression and top-load box compression results indicate good agreement between these properties of the U.S. and Enso Gutseit combined boards and boxes. The agreement between U.S. and Svenska Cellulosa combined boards and boxes is reasonably good but not as good as that between U.S. and Enso Gutseit combined boards and boxes.

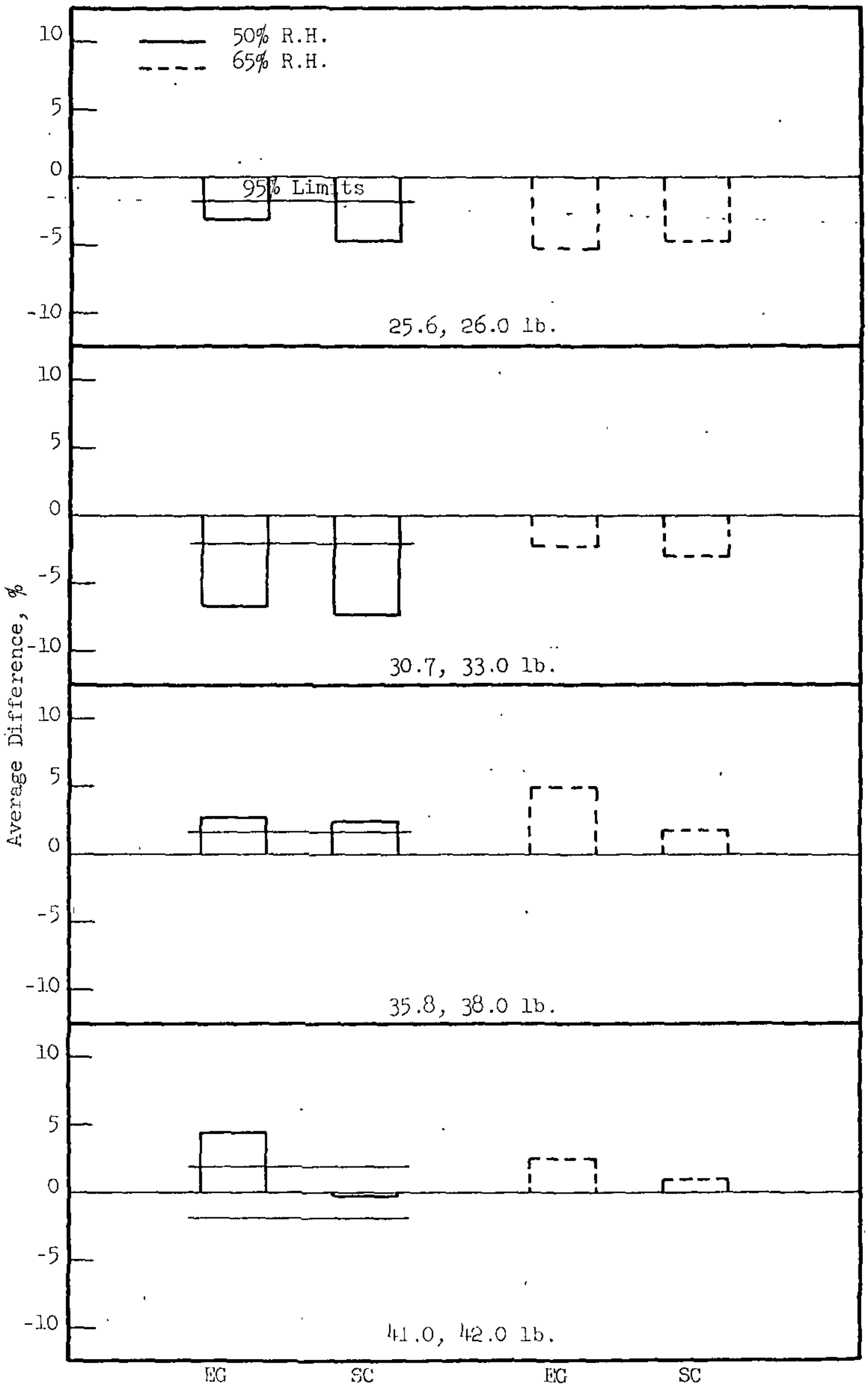


Fig. 11. Effect of Type of Linerboard on Combined Board Cross

The flexural stiffness of a material is the resistance with which a material resists bending. As previously mentioned, flexural stiffness is one of the basic properties of corrugated board which influence box compression. It enters the relationship as the geometric mean [see Equation (1)]. Examination of Equation (1) reveals that although flexural stiffness is one of the two basic material properties which determine box compression, its importance is secondary to edgewise compression as may be noted from the magnitude of the exponents associated with these properties in Equation (1).

The flexural stiffness results expressed as the geometric mean are tabulated in Tables XVI and XVII for 50 and 65% R.H., respectively. It may be seen that with one exception the geometric mean of the flexural stiffness of the combined boards made with U.S. linerboards is lower than the corresponding results on combined boards made with European linerboards. The exception is the combined board made with 30.7-lb. grade weight Svenska Cellulosa linerboard which exhibits lower results than the corresponding board made with 33.0-lb. grade weight U.S. linerboard. For purposes of comparison, the composite average difference in the geometric mean of the flexural stiffness between combined boards made with European and domestic linerboards are tabulated as follows and illustrated graphically in Fig. 12.

U.S. Nominal Grade Weight, lb.	Composite Average Difference in Geometric Mean of Flexural Stiffness, %[a] 50% R.H. E.G.	50% R.H. S.C.	65% R.H. E.G.	65% R.H. S.C.
26.0	+7.6	+7.1	+13.9	+4.7
33.0	+9.0	-3.6	+10.6	-1.6
38.0	+38.3	+14.8	+34.4	+9.6
42.0	+36.6	+16.2	+32.9	+11.8

[a]Combined board made with U.S. linerboard used as reference.

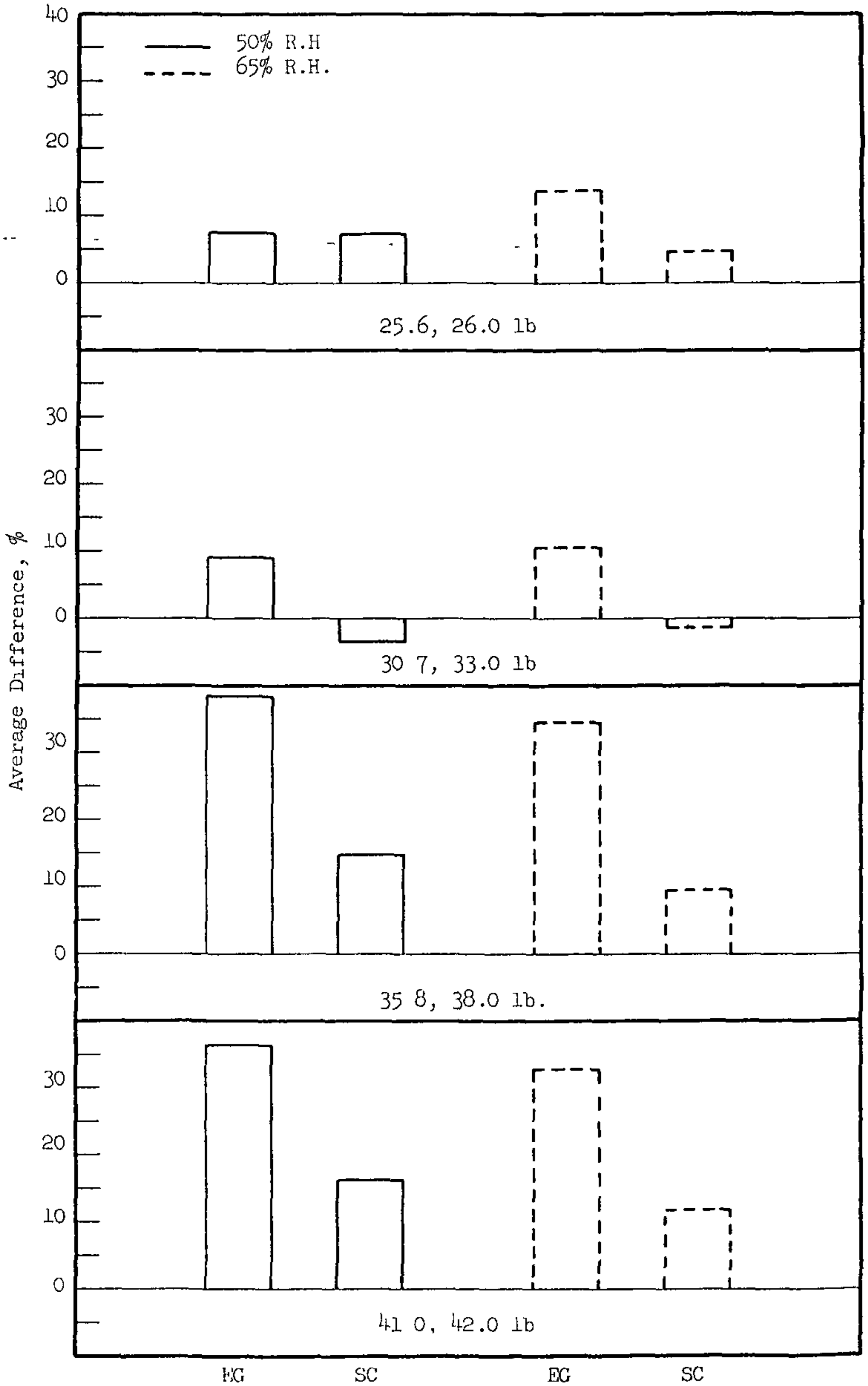


Figure 12. Effect of Type of Linerboard on Combined Board Geometric Mean of Flexural Stiffness

The flexural stiffness of corrugated board is primarily a function of the modulus of elasticity of the linerboards making up the facings and the caliper of the combined board; thus, the composite differences reflect the higher modulus of elasticity associated with the European linerboards in contrast to U.S. linerboards The greatest difference in flexural stiffness expressed as the geometric mean is at the two higher weight levels – i.e., 35 8, 38 0-lb. and 41 0, 42.0-lb. grade weight levels

As mentioned earlier in this report, a previous study (13) carried out at The Institute of Paper Chemistry has shown that top-load box compression is dependent on two basic combined board properties and the load perimeter as indicated by Equation (1). In order to determine the efficiency of this relationship when applied to the present study, top-load box compression results were calculated from the combined board results by means of Equation (1) and also an abridged form of Equation (1) which is based on an empirical relationship. The form of the abridged relationship is given in Equation (2),

$$P = 5.37\, P_m\, h^{0.508}\, Z^{0.492} \qquad (2)$$

where

P = top-load box compression, lb

P_m = combined board cross-machine edgewise compression, lb /in.

Z = box load perimeter ($2L + 2W$), inch

h = combined board caliper, inch

The predicted and observed top-load compression results are tabulated in Tables XIX and XX. It may be noted that Equations (1) and (2) predict top-load box compression very well for the B-flute boxes; however, the results obtained for the A-flute samples at 50 and 65% R H. exhibit considerably more

TABLE XIX

COMPARISON OF OBSERVED AND COMPUTED TOP LOAD COMPRESSION VALUES
(50% Relative Humidity)

Run	Liner Weight, lb/M sq ft	Medium Weight, lb/M sq ft	Top Load Compression, lb: Observed	Computed (Long Form)	Diff, %[a]	Computed (Short Form)	Diff, %[a]	Top Load Compression, lb: Observed	Computed (Long Form)	Diff, %[a]	Computed (Short Form)	Diff, %[a]
					A-Flute					B-Flute		
3	US-26	US-26	530	559	-5.4	573	+8.1	460	436	-5.2	449	-2.3
10	US-33	US-26	595	668	+12.2	635	+6.8	545	554	+1.7	562	+3.1
15	US-38	US-26	635	684	+7.7	681	+7.2	565	560	-0.8	571	+1.0
23	US-42	US-26	730	759	+4.0	733	+0.5	590	579	-1.9	591	+0.2
2	EG-25.6	US-26	510	538	+5.5	531	+4.0	445	427	-3.9	414	-6.9
7	EG-30.7	US-26	615	638	+3.7	576	-6.4	545	556	+2.0	529	-2.9
14	EG-35.8	US-26	690	738	+7.0	663	-3.9	600	626	+4.3	594	-1.1
19	EG-41.0	US-26	775	842	+8.7	771	-0.5	640	651	+1.7	619	-3.3
6	SC-25.6	US-26	520	517	-0.5	494	-4.9	440	439	-0.1	435	-1.2
11	SC-30.7	US-26	610	622	+1.9	585	-4.1	525	514	-2.0	513	-2.3
18	SC-35.8	US-26	640	720	+12.4	696	+8.7	590	558	-5.5	548	-7.1
22	SC-41.0	US-26	715	783	+9.5	729	+2.0	640	571	-10.8	555	-13.2
A			--	--	6.5	--	4.9	--	--	3.3	--	3.7
4	US-26	EUR-23	565	595	+5.3	606	+7.3	465	436	-6.3	443	-4.8
9	US-33	EUR-23	590	713	+20.9	681	+15.4	545	573	+5.1	577	+5.8
16	US-38	EUR-23	660	713	+8.0	701	+6.3	560	561	+0.2	569	+1.6
24	US-42	EUR-23	725	791	+9.1	768	+6.0	575	604	+5.1	616	+7.1
1	EG-25.6	EUR-23	520	588	+13.1	583	+12.2	435	471	+8.4	455	+4.6
8	EG-30.7	EUR-23	595	689	+15.8	626	+5.2	555	552	-0.5	531	-4.3
13	EG-35.8	EUR-23	675	782	+15.9	710	+5.2	635	621	-2.2	592	-6.8
20	EG-41.0	EUR-23	815	894	+9.7	801	-1.2	630	666	+5.8	627	-0.5
5	SC-25.6	EUR-23	530	562	+6.0	553	+4.4	435	458	+5.3	460	+5.9
12	SC-30.7	EUR-23	625	699	+11.9	665	+6.4	515	521	+1.2	505	-1.9
17	SC-35.8	EUR-23	630	766	+21.6	724	+14.9	585	606	+3.6	600	+2.6
21	SC-41.0	EUR-23	740	865	+16.9	823	+11.2	650	620	-4.6	615	-5.3
24D	US-26	EUR-26	545	608	+11.6	613	+12.4					
24C	US-33	EUR-26	655	744	+13.6	717	+9.5					
24B	US-38	EUR-26	645	745	+15.5	744	+15.4					
24A	US-42	EUR-26	730	795	+9.0	780	+6.9					
Av					12.1		8.8			4.0		4.3
Grand av					10.0		7.0			3.6		4.0

[a] Based on observed values as reference

Note Long form $\underline{P} = 2.0277\,\underline{P}_m^{0.7462}\,(\sqrt{D_x D_y})^{0.2538}\,\underline{Z}^{0.4924}$

Short form $\underline{P} = 5.8745\,\underline{P}_m\,\underline{h}^{0.5076}\,\underline{Z}^{0.924}$

COMPARISON OF OBSERVED AND COMPUTED TOP-LOAD COMPRESSION VALUES
(65% Relative Humidity)

Box	Liner Weight, lb./M sq. ft.	Medium Weight, lb./M sq. ft.	Top-Load Compression, lb. Observed	Computed (Long Form)	Diff., %a	Computed (Short Form)	Diff., %a	Top-Load Compression, lb. Observed	Computed (Long Form)	Diff., %a	Computed (Short Form)	Diff., %a
					A-Flute					B-Flute		
3	US-26	US-26	490	543	-10.8	560	-14.4	405	416	- 2.8	440	- 8.5
[illegible]	US-33	US-26	560	645	-15.2	632	-12.9	495	500	- 1.0	508	- 2.7
[illegible]	US-38	US-26	600	657	- 9.6	659	- 9.8	535	520	- 2.7	535	0.0
[illegible]	US-42	US-26	670	725	+ 9.2	726	- 8.3	570	551	- 3.3	559	- 1.9
2	[illegible]-25.6	US-26	465	540	-16.1	520	+11.8	425	406	- 4.5	398	- 6.3
[illegible]	[illegible]-30.7	US-26	540	645	-19.5	614	+13.6	510	515	- 0.9	511	- 0.2
[illegible]	[illegible]-35.8	US-26	605	723	-19.6	671	-10.9	570	572	- 0.3	545	- 4.4
[illegible]	[illegible]-41.0	US-26	750	802	- 6.9	748	- 0.3	620	607	- 2.2	577	- 7.0
6	SC-25.6	US-26	470	517	+ 9.9	509	- 8.4	405	422	- 4.2	424	+ 4.8
[illegible]	SC-30.7	US-26	545	615	-12.9	594	- 9.0	495	483	- 2.4	487	- 1.5
[illegible]	SC-35.8	US-26	625	669	- 6.9	654	- 4.6	570	525	- 7.9	525	- 7.9
[illegible]	SC-41.0	US-26	685	751	- 9.6	728	- 6.3	590	557	- 3.9	538	- 7.3
Average					12.1		9.2			3.0		4.4
1	US-26	EUR.-23	520	574	-10.3	591	-13.7	450	424	- 5.8	447	- 0.8
[illegible]	US-33	EUR.-23	540	669	-24.0	664	-23.0	500	516	- 3.2	524	+ 4.7
[illegible]	US-38	EUR.-23	600	692	-15.3	696	-16.1	510	520	- 1.9	526	+ 3.1
[illegible]	US-42	EUR.-23	675	763	+13.0	772	+14.3	515	570	-10.6	586	+13.8
[illegible]	[illegible]-25.6	EUR.-23	515	571	-11.0	564	- 9.5	420	430	- 2.3	424	- 0.9
[illegible]	[illegible]-30.7	EUR.-23	545	669	-22.7	626	-14.8	480	515	- 7.2	505	- 5.2
[illegible]	[illegible]-35.8	EUR.-23	620	754	-23.7	711	-16.5	620	610	- 1.7	590	- 4.9
[illegible]	[illegible]-41.0	EUR.-23	735	826	-12.3	781	- 6.3	600	628	- 4.6	589	- 1.8
[illegible]	[illegible]-25.6	EUR.-23	455	543	-19.4	534	-17.3	395	427	- 8.2	434	+ 9.9
[illegible]	[illegible]-30.7	EUR.-23	575	653	-13.6	651	-13.2	470	511	- 8.6	522	-11.1
[illegible]	[illegible]-35.8	EUR.-23	615	718	-16.8	703	-14.3	525	561	- 6.8	558	- 6.4
[illegible]	[illegible]-41.0	EUR.-23	625	786	-25.8	775	-24.1	580	577	- 0.5	575	- 0.8
[illegible]	US-26	EUR.-26	495	568	+14.8	588	+18.8					
[illegible]	US33	EUR.-26	580	675	+16.3	674	+16.2					
24B	US-38	EUR.-26	605	694	+14.8	710	+17.3					
24A	US-42	EUR.-26	645	738	+14.5	742	+15.1					
Average					16.8		15.7			5.1		5.3
Grand average					14.8		12.9			4.0		4.7

aBased on observed values as reference.

Note: Long form: $P = 2.028\ P_m^{0.746}\ (\sqrt{E_x E_y})^{0.254}\ Z^{0.492}$

Short form: $P = 5.87\ P_m\ h^{0.50}\ Z^{0.492}$

"error" than has been experienced heretofore when applied to A-flute board. It may be seen that even in spite of the greater than normal disparity exhibited by the A-flute box results, edgewise compression and flexural stiffness of the combined board (together with load perimeter) permit a far more accurate prediction of box compression than can be obtained with bursting strength.

Comparison of the flat crush results in Tables XVI and XVII, respectively, for 50 and 65% R.H., reveals that, with the possible exception of the results at the 25.6, 26.0-lb. grade weight level, there appears to be no significant difference in the flat crush of combined boards made with European and domestic linerboards fabricated with the same corrugating mediums. At the 25.6, 26.0-lb. grade weight level, the combined boards made with U.S. linerboard generally exhibit higher flat crush than the corresponding combined boards made with European linerboard. These differences are considered fortuitous inasmuch as the linerboard should have no effect on flat crush. For ready comparison, the composite average differences in flat crush have been tabulated as follows:

U.S. Nominal Grade Weight, lb.	Composite Average Differences in Flat Crush, %[a] 50% R.H.		65% R.H.	
	E.C.	S.C.	E.C.	S.C.
26.0	-7.6	-3.2	-5.8	-7.0
33.0	+0.2	+0.2	+2.0	+2.7
38.0	+1.2	-0.7	-4.2	-1.2
42.0	-0.5	-1.2	+0.9	+0.7

[a]Combined board made with U.S. linerboard used as reference.

It may be noted from a comparison of the pin adhesion results tabulated in Tables XVI and XVII, respectively, for 50 and 65% R.H., that with few exceptions the adhesion strength is higher on combined boards made with U.S. linerboards than on the corresponding combined boards made with European linerboards For ready comparison, the composite average differences in pin adhesion follow and are graphically illustrated in Fig 13.

U.S. Nominal Grade Weight, lb.	Composite Average Difference in Pin Adhesion, %[a]			
	50% R.H.		65% R.H.	
	E.G.	S.C.	E.G.	S.C
26.0	-19 0	-15.5	-9.3	-20.4
33 0	-22.8	-5.3	-15 1	-15.1
38 0	-12.5	-6.3	-4.3	-6.5
42 0	-5 7	0 0	-15.7	-3 9

[a]Combined board made with U.S. linerboard used as reference

It may be seen that the greatest differences occur at the two lowest linerboard grade weight levels It is believed that the poorer adhesion strength associated with the European combined boards is due to a large extent to the fact that they are less porous

Comparisons of the Physical Properties of U S and European Linerboard

It was noted earlier that during the corrugating of the fifty-two different combinations, samples or test strips from across the full width of each component roll were taken at the "start" and "end" of each material combination run on the corrugator. The "start" and "end" samples of each component for each material combination were evaluated separately and the results averaged to characterize the quality of each component (single-face liner, double-face liner, and corrugating medium) used in each material combination The results obtained on the samples of linerboard (segregated as to single- and

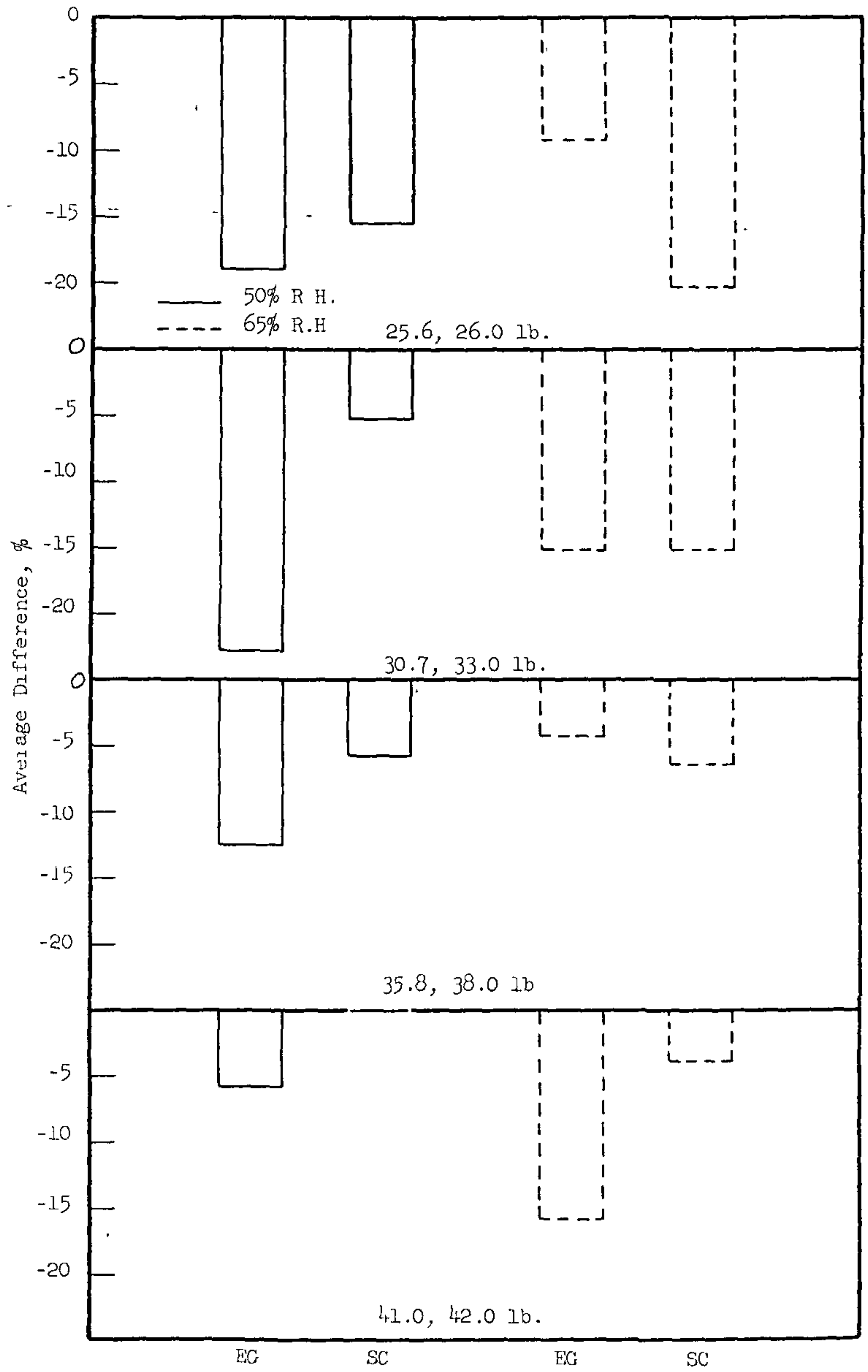


Figure 13. Effect of Type of Linerboard on Combined Board Pin

double-face liner) used in the fabrication of the A-flute combined board and boxes are tabulated in Tables XXI and XXII, respectively, for 50 and 65% R.H. The corresponding results for the components used in the fabrication of the B-flute combined board and boxes are tabulated in Tables XXIII and XXIV, respectively, for 50 and 65% R.H. The averages tabulated in Tables XXI through XXIV for a given material have been combined to give an over-all assessment of the physical characteristics of the twelve linerboards used in this study. The over-all averages for the linerboards are tabulated in Tables XXV through XXXII for the 50 and 65% R.H. The per cent differences in physical properties are summarized for each linerboard grade weight in Tables XXXIII and XXXIV for 50 and 65% R.H., respectively. For purpose of comparison, the per cent differences in linerboard basis weight at the four grade weight levels follow and are graphically illustrated in Fig. 14:

Nominal Wt., lb./M sq.ft.	Linerboard Basis Weight Difference, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard Weight, lb./M sq.ft.	E.G.	S.C.	U.S. Linerboard Weight, lb./M sq.ft.	E.G.	S.C.
26.0	28.0	-5.4	-4.6	28.2	-2.8	-4.3
33.0	35.0	-9.1	-11.4	35.7	-9.2	-11.8
[illegible]	39.4	-5.1	-7.6	40.0	-4.8	-6.2
[illegible]	42.8	-2.8	-7.5	43.7	-3.0	-8.5

[a] U.S. linerboard results used as reference.

As pointed out previously, the U.S. linerboards are 3 to 11% higher in weight than their European counterparts. The greatest disparity is at the 30.7, 33.0-lb. grade weight level and least at the 25.6, 26.0-lb. grade weight level. In general, the Svenska Cellulosa linerboards were lowest in weight.

TABLE XVI

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING A-FLUTE BOARD

(50% Relative Humidity)

Runs	Grade	Position	Weight, lb /M sq ft	Caliper, pt	App Density	Bursting Strength, psi Max	Min	Av	Elmendorf Tear, g /sheet In	Cross	Av	Torsion Tear, in -oz In	Cross	Av	Puncture, units In	Cross	Av	Modified Ring Compression, lb /in In	Cross	Taber Stiffness, g -cm In	Cross
A1, 2	EG-25.6	SF	26.4	7.8	3.4	115	86	100	169	208	188	45	48	46	18	18	18	16.1	11.3	19	8
		DF	26.4	7.9	3.3	119	82	102	164	200	182	44	49	46	18	18	18	16.1	11.4	20	8
		Av	26.4	7.8	3.4	117	84	101	166	204	185	44	48	46	18	18	18	16.1	11.4	20	8
A3, 4	US-26	SF	27.8	9.7	2.8	83	53	72	198	248	223	49	56	52	19	20	20	15.6	11.2	26	9
		DF	28.1	9.6	3.0	83	67	74	207	253	230	49	57	53	20	20	20	15.8	11.4	25	9
		Av	28.0	9.6	2.9	83	60	73	202	250	226	49	56	52	20	20	20	15.7	11.3	26	9
A5, 6	SC-25.6	SF	26.7	7.8	3.4	124	68	106	150	180	165	45	52	48	15	16	16	16.6	11.5	22	8
		DF	26.4	7.8	3.4	122	97	110	140	192	165	44	51	48	16	16	16	17.8	12.0	21	8
		Av	26.6	7.8	3.4	123	82	108	145	186	165	44	52	48	16	16	16	17.2	11.8	22	8
A7, 8	EG-30.7	SF	31.8	8.8	3.6	142	88	122	185	254	219	49	56	52	20	22	22	21.3	15.0	38	12
		DF	31.8	8.7	3.6	145	107	124	206	250	228	49	55	52	22	21	21	21.8	15.5	39	14
		Av	31.8	8.8	3.6	144	98	123	196	252	224	49	56	52	21	22	22	21.6	15.2	38	13
A9, 10	US-33	SF	35.0	9.8	3.6	117	95	108	237	307	272	60	72	66	24	24	24	23.7	15.9	41	14
		DF	35.0	9.8	3.6	120	90	105	240	308	274	61	74	68	24	25	24	23.7	16.3	40	14
		Av	35.0	9.8	3.6	118	92	106	238	308	273	60	73	67	24	24	24	23.7	16.1	40	14
A11, 12	SC-30.7	SF	31.2	9.8	3.2	140	88	114	212	232	222	54	51	52	20	22	20	19.8	14.2	44	14
		DF	30.4	9.6	3.2	143	83	111	206	236	221	55	52	53	20	20	20	19.6	14.0	40	14
		Av	30.8	9.7	3.2	142	86	112	209	234	222	54	52	52	20	21	20	19.7	14.1	42	14
A13, 14	EG-35.8	SF	37.2	10.0	3.7	162	100	130	248	302	276	52	60	56	25	26	26	25.3	17.2	55	20
		DF	37.4	10.1	3.7	172	102	142	249	304	276	48	57	53	26	26	26	24.4	18.0	54	22
		Av	37.3	10.0	3.7	167	101	136	248	303	276	50	58	54	26	26	26	24.8	17.6	54	21
A15, 16	US-38	SF	39.5	11.0	3.6	115	85	98	266	344	306	72	84	77	28	28	28	24.4	15.9	53	16
		DF	39.0	11.2	3.4	117	85	96	274	334	304	69	81	75	28	28	28	23.2	15.2	53	16
		Av	39.2	11.1	3.5	116	84	97	270	339	305	70	82	76	28	28	28	23.8	15.6	53	16
A17, 18	SC-35.8	SF	35.6	10.0	3.6	151	110	134	238	295	266	60	58	59	24	24	24	23.4	16.4	50	19
		DF	37.4	9.8	3.8	169	117	140	253	285	269	66	70	68	26	26	26	22.8	16.8	48	[illegible]
		Av	36.5	9.9	3.7	160	114	137	246	290	268	65	64	64	25	25	25	23.1	16.6	49	19
A19, 20	EG-41	SF	41.9	11.7	3.6	196	109	146	291	353	322	58	70	64	30	32	32	23.4	17.0	80	[illegible]
		DF	41.4	11.4	3.6	174	117	148	282	355	318	59	74	66	31	32	32	22.4	16.6	75	30
		Av	41.6	11.6	3.6	185	113	147	286	354	320	58	72	65	30	32	32	22.9	16.8	78	30
A23, 24, 24A	US-42	SF	42.6	12.0	3.6	136	102	116	288	366	327	65	82	74	32	33	32	19.8	15.8	67	[illegible]
		DF	42.8	12.0	3.6	135	100	116	295	358	326	72	87	80	32	32	32	19.0	15.3	67	[illegible]
		Av	42.7	12.0	3.6	136	101	116	292	362	326	68	84	77	32	32	32	19.4	15.6	67	[illegible]
A21, 22	SC-41	SF	39.9	12.0	3.3	162	90	133	258	308	283	62	63	66	26	28	28	20.4	15.8	[illegible]	[illegible]
		DF	39.7	12.1	3.2	191	121	144	270	319	294	64	67	66	[illegible]	28	[illegible]	21.1	16.4	[illegible]	[illegible]
		Av	39.8	12.0	3.2	186	106	138	264	314	288	65	68	66	28	28	28	20.8	16.1	[illegible]	[illegible]
A24B	US-38	SF	39.4	11.0	3.6	118	84	103	268	344	306	71	82	76	28	28	28	22.8	15.6	52	11
		DF	39.4	11.4	3.4	117	85	100	266	342	304	69	82	76	28	30	29	24.0	15.4	54	11
		Av	39.4	11.2	3.5	118	84	102	267	343	305	70	82	76	28	29	28	23.4	15.5	53	11
A24C	US-33	SF	35.2	9.8	3.6	117	95	106	236	310	273	64	74	68	24	25	24	24.2	16.2	42	14
		DF	35.1	9.8	3.6	114	84	103	228	310	270	62	74	68	24	25	24	23.2	16.1	40	14
		Av	35.2	9.8	3.6	116	90	104	232	310	272	63	74	68	24	25	24	23.7	16.2	41	14
A24D	US-26	SF	27.8	9.8	2.8	82	57	72	198	250	224	48	56	52	19	20	20	15.6	11.1	26	10
		DF	28.0	9.6	2.9	83	65	74	202	254	228	50	56	54	19	19	19	15.8	[illegible]	25	10
		Av	27.9	9.7	2.8	82	61	73	200	252	226	49	56	53	19	20	20	15.7	11.3	26	10

TABLE XXI (Continued)

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING A-FLUTE BOARD
(50% Relative Humidity)

Runs	Grade	Position	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross	Modulus of Elasticity, p.s.i. x 10^3 In	Modulus of Elasticity, p.s.i. x 10^3 Cross	TEA, in.-lb./sq. in. In	TEA, in.-lb./sq. in. Cross	IPC Bond Strength, kp.-cm./sec. In	IPC Bond Strength, kp.-cm./sec. Cross	Porosity, sec./100 cc.	Bendtsen Smoothness	Cobb Size, g./sq. m.
A1, 2	EG-25.6	SF	78.6	30.8	2.0	4.5	975	378	.96	1.00	2.74	2.91	25	712	37.8
		DF	79.6	30.6	1.9	4.5	992	365	.96	1.00	3.61	2.19	23	783	38.3
		Av.	79.1	30.7	2.0	4.5	984	372	.96	1.00	3.18	2.55	24	748	38.0
A3, 4	US-26	SF	57.2	22.0	1.8	3.2	658	264	.70	.55	3.64	2.66	12	1010	38.8
		DF	57.0	22.3	2.0	2.9	635	283	.72	.50	4.74	2.42	14	1030	37.9
		Av.	57.1	22.2	1.9	3.0	646	274	.71	.52	4.19	2.54	13	1020	38.4
A5, 6	SC-25.6	SF	91.4	26.4	2.2	5.0	1070	324	1.26	1.00	3.90	2.78	40	762	38.2
		DF	89.6	26.6	2.2	4.8	1006	332	1.22	.96	5.18	1.94	42	794	37.2
		Av.	90.5	26.5	2.2	4.9	1038	328	1.24	.98	4.54	2.36	41	778	37.7
A7, 8	EG-30.7	SF	106.8	37.1	2.0	4.2	1136	418	1.32	1.14	3.28	2.36	142	1020	44.3
		DF	106.6	38.2	2.0	4.2	1240	456	1.34	1.18	5.04	2.53	137	930	43.0
		Av.	106.7	37.6	2.0	4.2	1188	437	1.33	1.16	4.16	2.44	140	975	43.6
A9, 10	US-33	SF	86.8	30.0	2.2	3.6	889	354	1.24	.84	3.84	2.36	37	468	35.4
		DF	85.8	30.8	2.2	3.7	857	364	1.24	.87	4.88	1.96	38	430	36.2
		Av.	86.3	30.4	2.2	3.6	873	359	1.24	.86	4.36	2.16	38	449	35.8
A11, 12	SC-30.7	SF	99.6	39.4	1.8	5.1	912	348	1.20	1.44	5.04	2.96	28	810	38.8
		DF	96.7	38.6	2.0	5.0	877	348	1.22	1.40	7.97	2.98	24	912	38.4
		Av.	98.2	39.0	1.9	5.0	894	348	1.21	1.42	6.50	2.97	26	861	38.6
A13, 14	EG-35.8	SF	114.3	46.0	1.8	3.6	1126	460	1.32	1.20	3.06	2.54	162	1150	36.4
		DF	117.4	48.6	1.8	3.2	1100	483	1.35	1.10	4.76	1.96	113	784	35.8
		Av.	115.8	47.3	1.8	3.4	1113	472	1.34	1.15	3.91	2.25	138	967	36.1
A15, 16	US-38	SF	86.9	29.2	2.0	4.4	792	282	1.18	1.00	3.40	1.86	29	543	35.8
		DF	85.0	28.9	2.0	4.4	784	281	1.10	1.00	3.34	1.54	26	692	38.2
		Av.	86.0	29.0	2.0	4.4	788	282	1.14	1.00	3.37	1.70	28	618	37.0
A17, 18	SC-35.8	SF	107.9	46.4	2.2	5.4	933	378	1.58	1.78	4.13	2.67	51	585	37.6
		DF	113.1	45.6	2.4	5.6	983	381	1.69	1.82	7.03	2.62	82	336	37.2
		Av.	110.5	46.0	2.3	5.5	958	380	1.64	1.80	5.58	2.64	66	460	37.4
A19, 20	EG-41	SF	127.8	50.9	1.8	3.6	1080	446	1.54	1.33	3.43	2.82	119	1130	32.9
		DF	124.4	51.6	1.8	3.2	1048	464	1.50	1.16	4.40	1.66	102	756	32.4
		Av.	126.1	51.2	1.8	3.4	1064	455	1.52	1.24	3.92	2.24	110	943	32.6
A23, [illegible], 24A	US-42	SF	95.2	33.6	2.2	4.0	764	305	1.58	1.02	3.44	2.72	26	638	34.2
		DF	95.8	32.2	2.2	3.5	791	306	1.57	.87	6.22	1.80	32	596	33.2
		Av.	95.5	32.9	2.2	3.8	778	306	1.58	.94	4.83	2.26	29	617	33.7
A21, 22	SC-41	SF	124.7	47.0	2.0	4.7	934	340	1.54	1.60	5.19	3.28	82	1020	38.0
		DF	128.6	46.5	1.9	4.8	954	328	1.58	1.63	5.98	1.94	52	981	37.8
		Av.	126.6	46.8	2.0	4.8	944	334	1.56	1.62	5.58	2.61	67	1000	37.9
[illegible]	US-38	SF	85.8	28.8	2.0	4.2	787	283	1.13	.96	3.83	1.96	28	548	36.4
		DF	85.6	28.8	2.0	4.4	780	274	1.10	.98	4.12	1.76	26	670	38.2
		Av.	85.7	28.8	2.0	4.3	784	278	1.12	.97	3.98	1.86	27	609	37.3
[illegible]	US-33	SF	87.7	30.1	2.2	3.6	889	354	1.27	.84	3.34	3.00	36	460	35.6
		DF	87.2	30.2	2.2	3.6	875	360	1.28	.82	4.04	2.05	39	422	36.0
		Av.	87.4	30.2	2.2	3.6	882	357	1.28	.83	3.69	2.52	38	441	35.8
[illegible]	US-26	SF	58.6	22.2	1.9	3.4	662	270	.74	.58	3.16	2.39	13	991	37.2
		DF	57.8	22.1	2.0	3.1	644	276	.73	.52	5.13	2.32	12	1050	38.3
		Av.	58.2	22.2	2.0	3.2	653	273	.74	.55	4.14	2.36	12	1020	37.8

TABLE XXII

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING A-FLUTE BOARD AT 65% R.H.

Runs	Liner Grade	Position	Weight, lb./M sq. ft.	Caliper, pt.	Apparent Density	Bursting Strength, p.s.i. Max.	Min.	Av.	Elmendorf Tear, g./sheet In	Cross	Av.	Torsion Tear, in.-oz. In	Cross	Av.	Puncture, unit In	Cross	Av.	Modified Ring Compression, lb./inch In	Cross
A1,2	EG-25.6	S.F.	27.1	8.0	3.4	110	76	95	187	232	210	52	58	54	18	20	20	16.0	10.6
		D.F.	28.4	7.9	3.6	107	87	98	187	224	206	51	56	54	18	18	18	15.6	10.8
		Av.	27.8	8.0	3.5	108	82	96	187	228	208	52	57	54	18	19	19	15.8	10.7
A3,4	US-26	S.F.	27.6	10.0	2.8	80	59	70	227	286	256	55	67	61	20	20	20	15.2	10.7
		D.F.	28.7	9.8	2.9	81	59	70	230	284	258	60	69	64	20	21	21	15.8	11.0
		Av.	28.2	9.9	2.8	80	59	70	228	285	257	58	68	62	20	20	20	15.5	10.8
A5,6	SC-25.6	S.F.	27.0	8.0	3.4	125	93	106	167	208	188	56	64	60	16	16	16	16.6	11.0
		D.F.	26.7	8.0	3.4	130	92	108	153	211	182	52	62	57	16	16	16	16.6	11.0
		Av.	26.8	8.0	3.4	128	92	107	160	210	185	54	63	58	16	16	16	16.6	11.0
A7,8	EG-30.8	S.F.	32.5	8.9	3.7	145	100	123	214	284	249	54	70	62	22	22	22	21.8	14.1
		D.F.	32.2	8.9	3.6	147	93	122	236	283	260	56	66	62	22	22	22	21.6	14.5
		Av.	32.4	8.9	3.6	146	96	122	225	284	254	55	68	62	22	22	22	21.7	14.3
A9,10	US-33	S.F.	35.6	10.0	3.6	117	94	103	272	344	308	66	85	76	24	25	25	23.4	15.0
		D.F.	36.0	10.0	3.6	115	88	104	270	348	309	67	86	76	26	26	26	23.3	15.0
		Av.	35.8	10.0	3.6	116	91	104	271	346	308	66	86	76	25	26	26	23.4	15.0
A11,12	SC-30.8	S.F.	31.6	10.0	3.2	144	96	116	264	281	272	64	62	62	22	22	22	19.3	14.0
		D.F.	31.1	9.8	3.2	137	99	114	240	266	252	64	62	63	22	21	22	20.0	14.0
		Av.	31.4	9.9	3.2	140	98	115	252	274	262	64	62	62	22	22	22	19.9	14.0
A13,14	EG-35.9	S.F.	38.2	10.4	3.6	163	102	134	274	342	308	62	78	71	28	29	28	25.3	16.5
		D.F.	38.0	10.4	3.6	169	104	138	301	354	328	62	74	68	28	28	28	23.6	16.6
		Av.	38.1	10.4	3.6	166	103	136	286	348	318	62	76	70	28	28	28	24.4	16.6
A15,16	US-38	S.F.	40.2	11.3	3.6	125	86	100	315	388	352	76	92	83	30	30	30	24.7	14.8
		D.F.	39.6	11.6	3.4	120	69	94	302	384	343	77	94	86	30	32	32	22.8	14.6
		Av.	39.9	11.4	3.5	122	78	97	308	386	248	76	93	84	30	31	31	23.8	14.7
A17,18	SC-35.9	S.F.	37.0	10.3	3.6	162	117	136	274	336	305	73	80	77	26	26	26	23.5	15.8
		D.F.	38.2	10.0	3.8	168	125	141	295	314	304	80	86	82	26	28	27	22.6	16.2
		Av.	37.6	10.2	3.7	165	121	138	284	325	304	76	83	80	26	27	26	23.0	16.0
A19,20	EG-41.0	S.F.	42.6	11.8	3.6	175	112	146	339	386	362	72	92	82	34	34	34	23.3	17.6
		D.F.	42.2	11.7	3.6	179	115	143	322	386	354	68	85	76	33	34	34	22.0	17.6
		Av.	42.4	11.8	3.6	177	114	144	330	386	358	70	88	79	34	34	34	22.6	17.6
A23,24, 24A	US-42	S.F.	43.6	12.4	3.5	136	101	115	320	394	357	79	102	90	34	34	34	20.6	16.2
		D.F.	43.7	12.4	3.5	128	100	114	324	402	363	82	104	93	34	34	34	20.4	15.9
		Av.	43.6	12.4	3.5	132	100	114	322	398	360	80	103	92	34	34	34	20.5	16.0
A21,22	SC-41.0	S.F.	40.0	12.4	3.2	175	104	139	307	354	331	76	79	78	30	30	30	20.8	16.4
		D.F.	40.6	12.4	3.3	169	106	143	300	351	326	76	82	79	30	31	30	21.3	16.0
		Av.	40.3	12.4	3.2	172	105	141	304	352	328	76	80	78	30	30	30	21.0	16.2
A24B	US-38	S.F.	40.2	11.5	3.5	125	75	99	308	388	348	74	92	83	31	32	32	25.0	14.9
		D.F.	40.0	11.7	3.4	115	69	94	299	385	342	77	94	86	31	32	32	24.4	14.8
		Av.	40.1	11.6	3.4	120	72	96	304	386	345	76	93	84	31	32	32	24.7	14.8
A24C	US-33	S.F.	35.9	10.0	3.6	113	94	104	264	348	306	66	86	76	26	26	26	23.4	14.6
		D.F.	36.0	10.0	3.6	115	95	106	274	348	311	64	86	75	26	26	26	22.9	15.1
		Av.	36.0	10.0	3.6	114	94	105	269	348	308	65	86	76	26	26	26	23.2	14.8
A24D	US-26	S.F.	28.2	10.0	2.3	88	59	69	217	278	248	54	66	60	20	20	20	15.5	10.8
		D.F.	28.5	9.8	2.9	79	59	70	228	279	253	56	68	63	21	22	22	15.7	10.9
		Av.	28.4	9.9	2.8	84	59	70	222	278	250	55	67	62	20	21	21	15.6	10.8

TABLE XXIII (Continued)

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING A-FLUTE BOARD AT 65% R.H.

Runs	Liner Grade	Position	Taber Stiffness, g.-cm. In	Taber Stiffness, g.-cm. Cross	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross	Modulus of Elasticity, p.s.i. x 10³ In	Modulus of Elasticity, p.s.i. x 10³ Cross	T.E.A., in.-lb./sq. in. In	T.E.A., in.-lb./sq. in. Cross	IPC Bonding Strength, kp.-cm./sec. In	IPC Bonding Strength, kp.-cm./sec. Cross	Porosity, sec./100 cc.	Bendtsen Smoothness, ml./min.	Cobb Size, g./sq. m.
A1,2	EG-25.6	S.F.	19	7	75.6	29.4	2.0	4.8	888	333	0.96	1.00	1.74	1.67	21	836	33.1
		D.F.	19	7	76.3	29.8	2.1	5.0	951	340	1.02	1.06	1.77	1.65	22	850	33.6
		Av.	19	7	75.0	29.6	2.0	4.9	920	336	0.99	1.03	1.76	1.66	22	843	33.4
A3,4	US-26	S.F.	25	9	51.8	20.8	2.0	4.2	588	234	0.72	0.67	1.93	1.76	12	1120	32.7
		D.F.	24	10	52.4	21.0	2.1	3.6	589	251	0.74	0.57	2.04	1.90	10	1070	34.4
		Av.	24	10	52.1	20.9	2.0	3.9	588	242	0.73	0.62	1.98	1.83	11	1095	33.6
A5,6	SC-25.6	S.F.	22	8	88.3	24.8	2.4	5.6	968	282	1.32	1.04	2.02	1.96	30	775	34.4
		D.F.	22	6	85.8	25.4	2.4	5.6	938	291	1.28	1.04	1.90	1.93	32	692	34.0
		Av.	22	7	87.0	25.1	2.4	5.6	953	286	1.30	1.04	1.96	1.94	31	734	34.2
A7,8	EG-30.8	S.F.	40	12	98.5	36.4	2.0	4.8	1070	374	1.30	1.24	2.08	1.96	124	991	40.6
		D.F.	36	13	100.4	36.2	2.2	4.8	1078	379	1.36	1.23	2.30	2.22	136	858	38.0
		Av.	38	12	99.4	36.3	2.1	4.8	1074	376	1.33	1.24	2.19	2.09	130	914	39.3
A9,10	US-33	S.F.	38	14	81.8	28.4	2.4	4.4	815	318	1.30	0.96	2.40	1.95	32	594	32.2
		D.F.	39	16	81.8	28.1	2.4	4.0	822	322	1.33	0.89	2.08	1.84	33	534	32.0
		Av.	38	15	81.8	28.2	2.4	4.2	818	320	1.32	0.92	2.24	1.90	32	564	32.1
A11,12	SC-30.8	S.F.	45	13	93.4	36.4	2.0	5.4	870	303	1.20	1.38	2.30	2.39	20	798	34.1
		D.F.	40	13	90.3	38.2	2.0	6.0	862	312	1.14	1.56	2.36	2.32	22	970	34.5
		Av.	42	13	91.8	37.3	2.0	5.7	866	308	1.17	1.47	2.33	2.36	21	884	34.3
A13,14	EG-35.9	S.F.	56	19	106.6	44.4	2.0	4.1	1040	406	1.32	1.26	2.13	1.98	117	1180	32.3
		D.F.	53	22	109.1	45.5	2.0	3.5	1030	424	1.38	1.12	1.76	1.90	110	707	32.8
		Av.	54	20	107.8	45.0	2.0	3.8	1035	415	1.35	1.19	1.94	1.94	114	944	32.6
A15,16	US-38	S.F.	53	16	82.4	27.4	2.2	5.0	754	254	1.25	1.06	2.06	1.73	34	646	32.2
		D.F.	52	16	76.8	26.4	2.2	5.2	681	233	1.10	1.04	1.82	2.16	20	758	34.2
		Av.	52	16	79.6	26.9	2.2	5.1	718	244	1.18	1.05	1.94	1.94	27	702	33.2
A17,18	SC-35.9	S.F.	49	18	101.4	43.9	2.5	5.8	869	335	1.64	1.76	2.24	2.12	49	545	33.7
		D.F.	48	16	106.4	43.8	2.4	6.4	930	337	1.68	1.92	2.24	1.88	64	315	32.0
		Av.	48	17	103.9	43.8	2.4	6.1	900	336	1.66	1.84	2.24	2.00	56	430	32.8
A19,20	EG-41.0	S.F.	88	29	126.8	49.0	2.0	4.0	997	394	1.50	1.40	2.36	2.12	114	1240	29.5
		D.F.	79	30	113.8	47.4	2.0	3.4	986	410	1.44	1.12	1.74	1.97	83	728	28.6
		Av.	84	30	115.3	48.2	2.0	3.7	992	402	1.47	1.26	2.05	2.04	98	984	29.0
A23, 24,24A	US-42	S.F.	68	23	89.8	31.4	2.4	4.2	722	269	1.40	1.02	2.36	1.96	25	693	30.0
		D.F.	67	24	89.3	31.2	2.4	4.2	720	276	1.39	1.02	1.92	1.90	26	634	29.4
		Av.	68	24	89.6	31.3	2.4	4.2	721	272	1.40	1.02	2.14	1.93	26	664	29.7
A21,22	SC-41.0	S.F.	84	26	114.6	43.6	2.2	5.0	828	299	1.54	1.58	3.01	2.32	80	1180	34.9
		D.F.	87	26	122.2	43.0	2.2	5.4	913	286	1.67	1.62	2.07	2.21	47	981	33.8
		Av.	86	26	118.4	43.3	2.2	5.2	870	292	1.60	1.60	2.54	2.26	64	1080	34.4
A24B	US-38	S.F.	53	16	79.0	27.1	2.2	5.1	710	242	1.19	1.08	2.11	1.66	26	683	32.3
		D.F.	52	16	77.6	27.0	2.2	5.2	684	240	1.11	1.10	1.78	1.92	22	774	34.4
		Av.	52	16	78.3	27.0	2.2	5.2	697	241	1.15	1.09	1.94	1.79	24	728	33.4
A24C	US-33	S.F.	39	14	81.4	28.4	2.4	4.4	807	314	1.28	0.96	2.74	1.93	33	594	32.7
		D.F.	39	16	80.2	28.0	2.4	4.2	822	322	1.29	0.90	2.24	2.05	36	523	32.2
		Av.	39	15	80.3	28.2	2.4	4.8	814	318	1.28	0.93	2.49	1.99	34	558	32.4
A24D	US-26	S.F.	26	10	52.2	20.6	2.0	4.0	591	236	0.73	0.63	2.14	1.76	11	1120	32.9
		D.F.	23	9	52.4	20.6	2.1	3.8	592	240	0.75	0.61	1.86	1.83	10	1120	34.6
		Av.	24	10	52.3	20.6	2.0	3.9	592	338	0.74	0.62	2.00	1.80	10	1120	33.8

TABLE XXIII

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING B-FLUTE BOARD
(50% Relative Humidity)

Runs	Liner Grade	Position	Weight, lb./M sq. ft.	Caliper, pt.	App. Density	Bursting Strength, p.s.i.g. Max.	Min.	Av.	Elmendorf Tear, g./sheet In	Cross	Av.	Torsion Tear, in.-oz. In	Cross	Av.	Puncture, unit In	Cross	Av.	Modified Ring Compression, lb./in. In	Cross
B1,2	EG-25.6	SF	26.6	7.8	3.4	112	86	99	167	206	186	45	48	46	18	19	18	15.4	11.0
		DF	26.6	7.9	3.4	119	87	99	163	200	182	45	48	46	18	18	18	16.8	11.4
		Av.	26.6	7.8	3.4	116	86	99	165	203	184	45	48	46	18	18	18	16.1	11.2
B3,4	US-26.0	SF	27.8	9.6	2.9	83	53	72	199	248	223	49	56	52	19	19	19	16.1	11.3
		DF	28.0	9.6	3.0	82	60	72	204	250	227	50	58	54	20	20	20	16.2	11.4
		Av.	27.9	9.6	3.0	82	56	72	202	249	225	50	57	53	20	20	20	16.2	11.4
B5,6	SC-25.6	SF	27.0	7.9	3.4	119	68	104	146	179	162	47	52	50	16	16	16	16.8	11.5
		DF	26.6	7.9	3.4	121	81	106	136	192	164	44	51	48	16	16	16	18.4	11.8
		Av.	26.8	7.9	3.4	120	74	105	141	186	163	46	52	49	16	16	16	17.6	11.6
B7,8	EG-30.7	SF	31.8	8.8	3.6	142	110	126	188	256	222	50	54	52	20	22	21	21.6	14.8
		DF	31.8	8.8	3.6	155	107	124	208	250	230	50	55	52	22	22	22	21.2	15.4
		Av.	31.8	8.8	3.6	148	108	125	198	253	226	50	54	52	21	22	22	21.4	15.1
B9,10	US-33.0	SF	35.0	9.8	3.6	117	95	104	240	308	274	59	74	66	24	24	24	23.5	15.6
		DF	35.1	9.9	3.6	120	89	105	246	308	276	59	74	66	24	25	24	22.7	15.9
		Av.	35.0	9.8	3.6	118	92	104	243	308	275	59	74	66	24	24	24	23.1	15.8
B11, 12	SC-30.7	SF	31.6	9.8	3.2	138	88	112	216	236	226	54	51	52	20	22	21	20.6	14.3
		Df	30.8	9.6	3.2	143	83	110	217	248	232	58	52	55	20	20	20	20.2	14.4
		Av.	31.2	9.7	3.2	140	86	111	216	242	229	56	52	54	20	21	20	20.4	14.4
B13, 14	EG-35.8	SF	37.4	10.0	3.8	163	100	134	246	304	276	50	58	54	26	26	26	24.6	17.6
		DF	37.4	10.0	3.7	170	91	136	243	310	276	52	62	57	26	26	26	24.2	18.2
		Av.	37.4	10.0	3.8	166	96	135	244	307	276	51	60	56	26	26	26	24.4	17.9
B15, 16	US-38.0	SF	39.8	11.2	3.6	109	83	98	279	352	316	69	81	75	28	28	28	25.0	15.9
		DF	39.4	11.1	3.6	122	86	98	282	346	314	74	86	80	28	28	28	23.6	15.2
		Av.	39.6	11.2	3.6	116	84	98	280	349	315	72	84	78	28	28	28	24.3	15.6
B17, 18	SC-35.8	SF	35.7	10.0	3.6	163	110	132	238	298	268	60	59	59	25	26	26	23.4	16.6
		DF	37.2	9.8	3.8	157	99	135	252	286	269	69	72	70	26	26	26	22.3	16.3
		Av.	36.4	9.9	3.7	160	104	134	245	292	268	64	66	64	26	26	26	22.8	16.4
B19, 20	EG-41.0	SF	41.9	11.6	3.6	172	105	144	287	345	316	60	70	66	32	32	32	23.0	16.2
		DF	41.4	11.4	3.6	174	105	144	296	360	328	59	72	66	31	31	31	21.4	16.6
		Av.	41.6	11.5	3.6	173	105	144	292	352	322	60	72	66	32	32	32	22.2	16.4
B23, 24	US-42.0	SF	42.8	12.2	3.5	129	99	114	294	366	330	68	84	76	32	33	32	18.8	15.1
		DF	43.0	12.2	3.5	132	95	114	291	366	328	78	92	85	32	32	32	19.5	15.4
		Av.	42.9	12.2	3.5	130	97	114	292	366	329	73	88	80	32	32	32	19.2	15.2
B21, 22	SC-41.0	SF	39.7	12.0	3.3	179	90	132	261	308	284	59	65	62	28	28	28	19.8	15.4
		DF	39.8	12.1	3.3	186	108	139	268	317	292	64	68	66	29	28	29	22.0	16.2
		Av.	39.8	12.0	3.3	182	99	136	264	312	288	62	66	64	28	28	28	20.9	15.8

TABLE XXIII (Continued)

Runs	Liner Grade	Position	Taber Stiffness, g.-cm. In	Taber Stiffness, g.-cm. Cross	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross	Modulus of Elasticity, p.s.i. x 10^3 In	Modulus of Elasticity, p.s.i. x 10^3 Cross	TEA, in.-lb./sq. in. In	TEA, in.-lb./sq. in. Cross	IPC Bond Strength, kp.-cm./sec. In	IPC Bond Strength, kp.-cm./sec. Cross	Porosity, sec./100 cc.	Bendtsen Smoothness	Cobb Size, g./sq. m.
B1,2	BG-25.6	SF	20	7	79.4	30.4	1.9	4.4	968	361	0.94	1.00	3.18	2.71	24	786	36.1
		DF	20	7	80.8	30.8	1.8	4.6	1020	358	0.95	1.02	3.74	1.59	24	828	36.5
		Av.	20	7	80.1	30.6	1.8	4.5	994	360	0.94	1.01	3.46	2.15	24	782	36.3
B3,4	US-26.0	SF	26	10	57.0	21.7	1.8	3.3	654	257	0.70	0.55	4.02	4.96	12	946	39.8
		DF	26	10	56.9	22.6	1.9	3.0	642	280	0.72	0.52	4.97	2.47	14	962	37.4
		Av.	26	10	57.0	22.2	1.8	3.2	648	268	0.71	0.54	4.50	3.72	13	954	38.6
B5,6	SC-25.6	SF	23	8	91.2	25.7	2.2	5.0	1057	307	1.26	0.98	4.42	3.48	38	974	37.0
		DF	22	7	87.2	26.6	2.1	4.8	1027	324	1.15	0.96	6.14	1.85	38	903	36.9
		Av.	22	8	89.2	26.2	2.2	4.9	1042	316	1.20	0.97	5.28	2.66	38	938	37.0
B7,8	BG-30.7	SF	38	12	107.8	37.1	2.0	4.4	1136	411	1.33	1.19	2.94	2.52	124	1080	44.4
		DF	35	14	106.8	39.0	2.0	4.4	1146	424	1.34	1.26	5.60	1.88	142	908	41.5
		Av.	36	13	107.3	38.0	2.0	4.4	1141	418	1.34	1.22	4.27	2.20	133	994	43.0
B9,10	US-33.0	SF	40	15	87.5	29.4	2.2	3.6	877	344	1.26	0.82	3.88	2.66	39	575	35.8
		DF	40	14	86.3	30.4	2.2	3.8	854	356	1.20	0.87	5.59	2.06	35	519	35.0
		Av.	40	14	86.9	29.9	2.2	3.7	866	350	1.23	0.84	4.74	2.36	37	547	35.4
B11, 12	SC-30.7	SF	46	13	98.4	39.0	1.8	5.1	928	338	1.12	1.42	4.82	3.34	26	768	38.2
		DF	40	16	97.0	39.6	2.0	5.2	872	350	1.20	1.46	9.76	3.39	24	832	37.8
		Av.	43	14	97.7	39.3	1.9	5.2	900	344	1.16	1.44	7.29	3.36	25	800	38.0
B13, 14	BG-35.8	SF	50	20	116.4	46.2	1.8	3.6	1111	455	1.37	1.23	3.92	2.62	153	988	35.3
		DF	54	22	119.8	47.9	1.8	3.2	1116	482	1.37	1.07	4.42	1.92	114	754	35.8
		Av.	52	21	117.8	47.0	1.8	3.4	1114	468	1.37	1.15	4.17	2.27	134	871	35.6
B15, 16	US-38.0	SF	54	16	86.4	28.6	2.0	4.2	769	274	1.16	0.95	2.56	1.66	32	625	33.8
		DF	52	16	85.4	29.0	2.0	4.6	784	278	1.13	1.04	3.64	1.66	28	603	38.2
		Av.	53	16	85.9	28.8	2.0	4.4	776	276	1.14	1.00	3.10	1.66	30	614	36.0
B17, 18	SC-35.8	SF	49	18	109.1	46.6	2.2	5.5	948	378	1.60	1.80	4.10	3.12	50	618	35.8
		DF	47	16	113.8	44.7	2.4	5.4	975	376	1.72	1.72	6.78	2.16	76	456	35.7
		Av.	48	17	111.4	45.6	2.3	5.4	962	377	1.66	1.76	5.44	2.64	63	537	35.8
B19, 20	BG-41.0	SF	79	28	125.2	49.5	1.8	3.5	1052	444	1.52	1.26	3.40	3.36	116	1120	32.4
		DF	76	32	124.2	50.9	1.8	3.2	1058	460	1.48	1.14	5.93	1.73	100	810	31.9
		Av.	78	30	124.7	50.2	1.8	3.4	1055	452	1.50	1.20	4.66	2.54	108	965	32.2
B23, 24	US-42.0	SF	68	23	94.8	33.4	2.2	4.0	760	294	1.36	1.03	3.16	2.88	26	880	32.7
		DF	68	24	95.2	32.4	2.1	3.6	769	296	1.30	0.90	6.19	1.68	30	685	32.6
		Av.	68	24	95.0	32.9	2.2	3.8	769	295	1.33	0.96	4.68	2.28	28	782	32.6
B21, 22	SC-41.0	SF	88	27	125.8	46.2	2.0	4.6	931	328	1.56	1.56	4.41	2.97	74	1060	36.2
		DF	86	26	126.4	45.9	1.9	4.7	954	328	1.52	1.56	7.85	2.12	54	1110	36.0
		Av.	87	26	126.1	46.0	2.0	4.6	942	328	1.54	1.56	6.13	2.54	64	1085	36.1

TABLE XXIV

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING B-FLUTE BOARD AT 65% R H

Rolls	Liner Grade	Position	Weight, lb /M ft 2	Caliper, pt	Apparent Density	Bursting Strength, p s i Max	Bursting Strength, p s i Min	Bursting Strength, p s i Av	Elmendorf Tear, g /sheet In	Elmendorf Tear, g /sheet Cross	Elmendorf Tear, g /sheet Av	Torsion Tear, in - oz In	Torsion Tear, in - oz Cross	Torsion Tear, in - oz Av	Puncture, unit In	Puncture, unit Cross	Puncture, unit Av	Modified Ring Compression, lb /in In	Modified Ring Compression, lb /in Cross	Taber, Stiffness, g - cm In	Taber, Stiffness, g - cm Cross
B1, 2	EG-25 6	S F	27.2	8.0	3.4	110	87	96	190	230	210	52	58	54	19	19	19	15.5	10.4	20	7
		D F	27.0	7.8	3.4	105	85	98	188	226	206	52	56	54	18	19	19	16.6	10.8	20	6
		Av	27.1	7.9	3.4	108	86	97	189	228	208	52	57	54	18	19	19	16.0	10.6	20	6
B3, 4	JS-26	S F	27.7	10.0	2.8	80	62	72	225	286	256	54	66	60	21	21	21	15.4	10.7	26	9
		D F	28.6	9.9	2.9	81	59	70	231	283	232	60	68	64	21	21	21	15.5	10.8	25	10
		Av	28.2	10.0	2.8	80	60	71	228	234	244	57	67	62	21	21	21	15.4	10.8	26	10
B5 6	SC-25.6	S F	27.2	8.0	3.4	125	95	106	166	204	185	54	63	58	16	16	16	15.6	10.5	23	8
		D F	27.0	8.1	3.4	130	92	108	156	212	184	50	62	56	16	16	16	15.7	11.0	23	6
		Av	27.1	8.0	3.4	128	94	107	161	208	184	52	62	57	16	16	16	16.6	10.8	23	7
B7 8	EC-30 8	S F	32.5	8.9	3.7	140	108	125	215	279	247	53	69	61	22	22	22	21.4	13.6	42	12
		D F	32.2	8.8	3.6	147	93	122	240	288	264	56	68	62	22	22	22	21.6	14.6	34	14
		Av	32.4	8.8	3.6	144	100	124	228	284	256	54	68	62	22	22	22	21.5	14.1	38	13
B9, 10	US-33	S F.	35.5	10.0	3.6	120	93	105	266	338	302	70	84	77	25	25	25	22.8	15.0	38	14
		D F	35.7	10.0	3.6	115	87	101	272	337	305	68	84	76	25	26	25	23.3	14.6	40	14
		Av	35.6	10.0	3.6	118	90	103	269	338	304	69	84	76	25	26	25	23.0	14.8	39	14
B11, 12	SC-30 8	S F	32.1	10.0	3.2	146	99	117	260	280	270	64	62	62	22	23	22	20.6	14.2	46	13
		D.F	31.2	9.8	3.2	143	98	117	240	266	254	64	62	64	21	20	20	19.7	14.0	40	14
		Av	31.6	9.9	3.2	144	98	117	250	273	262	64	62	63	22	22	21	20.2	14.1	43	14
B13, 14	EG-35.9	S F.	38.1	10.4	3.7	157	102	133	281	342	311	64	76	70	28	29	28	25.6	16.2	54	20
		D F	38.1	10.2	3.8	167	104	136	286	354	320	62	73	68	28	28	28	24.2	17.2	54	22
		Av	38.1	10.3	3.8	162	103	134	284	348	316	63	74	69	28	28	28	24.9	16.7	54	21
B15, 16	JS-38	S.F	40.3	11.2	3.6	114	86	99	310	385	348	78	94	86	29	30	30	24.0	14.7	52	15
		D F	39.9	11.4	3.6	120	72	98	306	391	349	78	94	86	30	32	30	23.1	14.5	52	16
		Av	40.1	11.3	3.6	117	79	98	308	388	348	73	94	86	30	31	30	23.6	14.6	52	16
B17, 18	SC-35 9	S F	37.0	10.2	3.6	157	109	133	268	334	301	75	78	77	24	25	25	24.3	16.0	49	18
		D F	37.9	10.1	3.8	168	120	140	290	314	301	79	86	82	26	26	26	22.8	16.2	48	16
		Av	37.4	10.2	3.7	162	114	136	279	324	301	77	82	80	25	26	26	23.6	16.1	48	17
B19, 20R	EG-41 0	S F	42.8	11.8	3.6	175	119	144	316	382	349	72	90	81	34	34	34	22.5	17.4	84	29
		D F	42.2	11.8	3.6	176	106	143	322	382	352	67	84	76	32	34	32	22.2	17.6	77	30
		Av	42.5	11.8	3.6	176	112	144	319	382	350	70	87	78	33	34	33	22.4	17.5	80	30
B23, 24	US-42	S F.	43.8	12.5	3.5	132	98	112	329	399	364	84	104	94	34	34	34	21.4	15.8	68	22
		D.F.	43.9	12.5	3.5	128	92	111	332	410	370	92	104	94	34	35	34	20.5	15.6	67	26
		Av	43.8	12.5	3.5	130	95	112	330	404	367	83	104	94	34	34	34	21.0	15.7	68	24
B21, 22	SC-41 0	S F	39.6	12.5	3.1	177	104	143	302	348	326	79	81	80	30	28	29	20.6	16.4	86	24
		D F	40.1	12.4	3.2	181	106	140	302	350	326	74	81	78	30	30	30	21.4	16.0	90	25
		Av	39.3	12.5	3.2	179	105	142	302	349	326	76	81	79	30	29	30	21.0	16.2	88	24

TABLE XXIV (Continued)

PHYSICAL CHARACTERISTICS OF LINERS USED IN FABRICATING B-FLUTE BOARD AT 65% R.H.

Runs	Grade	Position	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross	Modulus of Elasticity, p.s.i. x 10^3 In	Modulus of Elasticity, p.s.i. x 10^3 Cross	T.E.A., in.-lb./sq. in. In	T.E.A., in.-lb./sq. in. Cross	IPC Bonding Strength, kp.-cm./sec. In	IPC Bonding Strength, kp.-cm./sec. Cross	Porosity, sec./100 cc.	Bendtsen Smoothness, ml./min.	Cobb Size, g./sq. m.
B1,2	EG-25.6	S.F.	75.2	29.8	2.0	5.0	922	324	0.94	1.03	1.72	1.72	21	803	32.2
		D.F.	76.6	29.6	2.0	5.1	968	336	0.98	1.06	1.86	1.64	22	745	32.6
		Av.	75.9	30.1	2.0	5.0	945	330	0.96	1.04	1.79	1.68	22	774	32.4
B3,4	US-26	S.F.	54.9	20.5	2.1	3.9	600	224	0.76	0.61	1.98	1.86	10	1180	33.8
		D.F.	52.0	20.8	2.1	3.5	583	248	0.73	0.56	1.90	1.88	10	1060	33.5
		Av.	53.4	20.6	2.1	3.7	592	236	0.74	0.58	1.94	1.87	10	1120	33.6
B5,6	SC-25.6	S.F.	88.4	25.2	2.3	5.8	968	276	1.28	1.08	1.93	1.90	31	795	33.8
		D.F.	88.8	25.8	2.4	5.6	938	290	1.34	1.06	2.05	1.88	36	790	32.8
		Av.	88.6	25.5	2.4	5.7	953	283	1.31	1.07	1.99	1.89	34	792	33.3
B7,8	EG-30.8	S.F.	98.8	36.4	2.0	4.8	1070	366	1.29	1.24	1.84	1.97	119	992	40.9
		D.F.	99.8	36.2	2.0	4.7	1102	385	1.30	1.22	2.30	2.32	122	808	37.6
		Av.	99.3	36.3	2.0	4.8	1086	376	1.30	1.23	2.07	2.14	120	900	39.2
B9,10	US-33	S.F.	80.7	28.2	2.3	4.2	815	314	1.24	0.91	2.13	2.04	32	638	36.1
		D.F.	81.8	28.3	2.4	4.2	807	311	1.29	0.92	2.06	1.73	29	660	32.0
		Av.	81.2	28.2	2.4	4.2	811	312	1.26	0.92	2.10	1.88	30	649	34.0
B11, 12	SC-30.8	S.F.	93.6	37.6	2.0	5.6	876	297	1.16	1.49	2.14	2.06	20	794	34.7
		D.F.	86.6	38.2	2.0	5.8	833	320	1.07	1.52	2.36	2.20	22	932	34.2
		Av.	90.1	37.9	2.0	5.7	854	308	1.12	1.50	2.25	2.13	21	863	34.4
B13, 14	EG-35.9	S.F.	109.3	44.4	2.0	4.0	1054	403	1.36	1.25	1.94	2.02	120	1060	30.8
		D.F.	110.0	44.9	2.0	3.4	1055	430	1.38	1.08	1.78	1.76	93	700	32.0
		Av.	109.6	44.6	2.0	3.7	1054	416	1.37	1.16	1.86	1.89	106	880	31.4
B15, 16	US-38	S.F.	82.2	27.7	2.2	5.0	766	252	1.19	1.06	2.06	1.81	36	610	30.2
		D.F.	80.2	26.8	2.2	5.2	715	245	1.21	1.06	1.74	1.88	22	650	34.3
		Av.	81.2	27.2	2.2	5.1	740	248	1.20	1.06	1.90	1.84	29	630	32.2
B17, 18	SC-35.9	S.F.	101.2	43.8	2.5	5.6	889	348	1.62	1.73	2.43	1.92	47	603	31.1
		D.F.	103.0	44.0	2.4	6.4	907	332	1.60	1.92	2.21	2.02	60	339	31.2
		Av.	102.1	43.9	2.4	6.0	898	340	1.61	1.82	2.32	1.97	54	471	31.2
B19, 20R	EG-41.0	S.F.	117.7	49.2	2.0	4.1	1007	397	1.47	1.41	2.28	2.11	122	1260	29.3
		D.F.	113.9	48.2	2.0	3.6	982	412	1.44	1.19	1.70	1.84	84	720	27.6
		Av.	115.8	47.8	2.0	3.8	994	404	1.46	1.30	1.99	1.98	103	990	28.4
B23, 24	US-42	S.F.	90.8	31.6	2.4	4.2	738	264	1.40	1.02	2.26	1.88	24	778	28.3
		D.F.	87.9	30.8	2.3	4.2	716	267	1.32	1.00	1.92	1.66	24	664	27.4
		Av.	89.4	31.2	2.4	4.2	727	266	1.36	1.01	2.09	1.77	24	721	27.8
B21, 22	SC-41.0	S.F.	113.0	41.9	2.0	4.6	838	292	1.41	1.42	2.54	2.10	65	1170	33.0
		D.F.	118.9	42.8	2.0	5.3	904	286	1.56	1.60	2.36	2.12	44	951	32.3
		Av.	116.0	42.4	2.0	5.0	871	289	1.48	1.51	2.45	2.11	54	1060	32.6

TABLE XXV

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 50% R.H.
(25.6-26.0-lb.)

Test Property[b]		US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %[a]	US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %[a]
							Unit Weight Basis				
Basis weight, lb./M sq. ft.		28.0	26.5	- 5.4	26.7	- 4.6	--	--	--	--	--
Caliper, pt.		9.6	7.8	- 18.8	7.8	- 18.8	--	--	--	--	--
Apparent density		3.0	3.4	+ 13.3	3.4	+ 13.3	--	--	--	--	--
Bursting strength, p.s.i.g.		72	100	+ 38.9	106	+ 47.2	2.57	3.77	+ 46.7	3.97	+ 54.5
Elmendorf tear, g./sheet	In	202	166	- 17.8	143	- 29.2	7.21	6.26	- 13.2	5.36	- 25.7
	Cross	250	204	- 18.4	186	- 25.6	8.93	7.70	- 13.8	6.97	- 21.9
	Av.	226	184	- 18.6	164	- 27.4					
Torsion tear, in.-oz.	In	50	44	- 12.0	45	- 10.0	1.79	1.66	- 7.3	1.69	- 5.6
	Cross	56	48	- 14.3	52	- 7.1	2.00	1.81	- 9.5	1.95	- 2.5
	Av.	52	46	- 11.5	48	- 7.7					
Puncture, unit	In	20	18	- 10.0	16	- 20.0	0.71	0.68	- 4.2	0.60	- 15.5
	Cross	20	18	- 10.0	16	- 20.0	0.71	0.68	- 4.2	0.60	- 15.5
	Av.	20	18	- 10.0	16	- 20.0					
Modified ring compression, lb./in.	In	16.0	16.1	+ 0.6	17.4	+ 8.8	0.57	0.61	+ 7.0	0.65	+ 14.0
	Cross	11.4	11.3	- 0.9	11.7	+ 2.6	0.41	0.43	+ 4.9	0.44	+ 7.3
Taber stiffness, g.-cm.	In	26	20	- 23.1	22	- 15.4					
	Cross	10	8	- 20.0	8	- 20.0					
Tensile, lb./in.	In	57.0	79.6	+ 39.6	89.8	+ 57.5	2.04	3.00	+ 47.1	3.36	+ 64.7
	Cross	22.2	30.6	+ 37.8	26.4	+ 18.9	0.79	1.15	+ 45.6	0.99	+ 25.3
Stretch, %	In	1.8	1.9	+ 5.6	2.2	+ 22.2					
	Cross	3.1	4.5	+ 45.2	4.9	+ 58.1					
Modulus of elasticity, p.s.i. x 10^3	In	647	989	+ 52.9	1040	+ 60.7					
	Cross	271	366	+ 35.1	322	+ 18.8					
T.E.A., in.-lb./sq. in.	In	0.71	0.95	+ 33.8	1.22	+ 71.8					
	Cross	0.53	1.00	+ 88.7	0.98	+ 84.9					
IPC bond strength, kp.-cm./sec.	In	4.34	3.32	- 23.5	4.91	+ 13.1					
	Cross	3.13	2.35	- 24.9	2.51	- 19.8					
Porosity, sec./100 cc.		13	24	+ 84.6	40	+207.7					
Bendtsen smoothness, ml./min.		987	765	- 22.5	858	- 13.1					
Cobb size, g./sq. m.		38.5	37.2	- 3.4	37.4	- 2.9					

[a] Based on US liner results as reference.

[b] Average of single and double face results for A- and B-flute.

TABLE XXVI

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 50% R.H.

(30.7-33.0-lb.)

Test Property[b]		US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %	US Liner	EG Liner	Diff., %	SC Liner	Diff., %
							Unit Weight Basis				
..is weight, lb./M sq. ft.		35.0	31.8	- 9.1	31.0	- 11.4	--	--	--	--	--
..iper, pt.		9.8	8.8	- 10.2	9.7	- 1.0	--	--	--	--	--
..arent density		3.6	3.6	0.0	3.2	- 11.1	--	--	--	--	--
..sting strength, p.s.i.g.		105	124	+ 18.1	112	+ 6.7	3.00	3.90	+ 30.0	3.61	+ 20.3
..endorf tear, g./sheet	In	240	197	- 17.9	212	- 11.7	6.86	6.19	- 9.8	6.84	- 0.3
	Cross	308	252	- 18.2	238	- 22.7	8.08	7.92	- 10.0	7.68	- 12.7
	Av.	274	225	- 17.9	226	- 17.5					
..ton tear, in.-oz.	In	60	50	- 16.7	55	- 8.3	1.71	1.57	- 8.2	1.77	+ 3.5
	Cross	74	55	- 25.7	52	- 29.7	2.11	1.73	- 18.0	1.68	- 20.4
	Av.	66	52	- 21.2	53	- 19.7					
..ture, unit	In	24	21	- 12.5	20	- 16.7	0.69	0.66	- 4.3	0.65	- 5.8
	Cross	24	22	- 8.3	21	- 12.5	0.69	0.69	0.0	0.68	- 1.4
	Av.	24	22	- 8.3	20	- 16.7					
..fied ring compression, lb./in.	In	23.4	21.5	- 8.1	20.0	- 14.5	0.67	0.68	+ 1.5	0.65	- 3.0
	Cross	16.0	15.2	- 5.0	14.2	- 11.2	0.46	0.48	+ 4.3	0.46	0.0
..r stiffness, g.-cm.	In	40	37	- 7.5	42	+ 5.0					
	Cross	14	13	- 7.1	14	0.0					
..le, lb./in.	In	86.6	107.0	+ 23.6	98.0	+ 13.2	2.47	3.36	+ 36.0	3.16	+ 27.9
	Cross	30.2	37.8	+ 25.2	39.2	+ 29.8	0.86	1.19	+ 38.4	1.26	+ 46.5
..ch, %	In	2.2	2.0	- 9.1	1.9	- 13.6					
	Cross	3.6	4.3	+ 19.4	5.1	+ 41.7					
..s of elasticity, ..i. x 103	In	870	1164	+ 33.8	897	+ 3.1					
	Cross	354	428	+ 20.9	346	- 2.3					
.., in.-lb./sq. in.	In	1.24	1.34	+ 8.1	1.18	- 4.8					
	Cross	0.85	1.19	+ 40.0	1.43	+ 68.2					
..nd strength, kp.-cm./sec.	In	4.55	4.22	- 7.3	6.90	+ 51.6					
	Cross	2.26	2.32	+ 2.7	3.16	+ 39.8					
..y, sec./100 cc.		38	136	+257.9	26	- 31.6					
..n smoothness, ml./min.		498	984	+ 97.6	830	+ 66.7					
..ize, g./sq. m.		35.6	43.3	+ 21.6	38.3	+ 7.6					

[a] ..d on US liner results as reference.

[b] ..age of single and double face results for A- and B-flute.

TABLE XXVII

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 50% R.H.

(35.8-38.0-lb.)

Test Property[b]		US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %	US Liner	EG Liner	Diff., %	SC Liner	Diff., %
							Unit Weight Basis				
Basis weight, lb./M sq. ft.		39.4	37.4	- 5.1	36.4	- 7.6	--	--	--	--	--
Caliper, pt.		11.2	10.0	- 10.7	9.9	- 11.6	--	--	--	--	--
Apparent density		3.6	3.8	+ 5.6	3.7	+ 2.8	--	--	--	--	--
Bursting strength, p.s.i.g.		98	136	+ 38.8	136	+ 38.8	2.49	3.64	+ 46.2	3.74	+ 50.2
Elmendorf tear, g./sheet	In	275	246	- 10.5	246	- 10.5	6.98	6.58	- 5.7	6.76	- 3.2
	Cross	344	305	- 11.3	291	- 15.4	8.73	8.16	- 6.5	7.99	- 8.5
	Av.	310	276	- 11.0	268	- 13.5					
Torsion tear, in.-oz.	In	71	50	- 29.6	64	- 9.9	1.80	1.34	- 25.6	1.76	- 2.2
	Cross	83	59	- 28.9	65	- 21.7	2.11	1.58	- 25.1	1.79	- 15.2
	Av.	77	55	- 28.6	64	- 16.9					
Puncture, unit	In	28	26	- 7.1	26	- 7.1	0.71	0.70	- 1.4	0.71	0.0
	Cross	28	26	- 7.1	26	- 7.1	0.71	0.70	- 1.4	0.71	0.0
	Av.	28	26	- 7.1	26	- 7.1					
Modified ring compression, lb./in.	In	24.0	24.6	+ 2.5	23.0	- 4.2	0.61	0.66	+ 8.2	0.63	+ 3.3
	Cross	15.6	17.8	+ 14.1	16.5	+ 5.8	0.40	0.48	+ 20.0	0.45	+ 12.5
Taber stiffness, g.-cm.	In	53	53	0.0	48	- 9.4					
	Cross	16	21	+ 31.2	18	+ 12.5					
Tensile, lb./in.	In	86.0	116.8	+ 35.8	111.0	+ 29.1	2.18	3.12	+ 43.1	3.05	+ 39.9
	Cross	28.9	47.2	+ 63.3	45.8	+ 58.5	0.73	1.26	+ 72.6	1.26	+ 72.6
Stretch, %	In	2.0	1.8	- 10.0	2.3	+ 15.0					
	Cross	4.4	3.4	- 22.7	5.4	+ 22.7					
Modulus of elasticity, p.s.i. x 10^3	In	782	1114	+ 42.5	960	+ 22.8					
	Cross	279	470	+ 68.5	378	+ 35.5					
T.E.A., in.-lb./sq. in.	In	1.14	1.36	+ 19.3	1.65	+ 44.7					
	Cross	1.00	1.15	+ 15.0	1.78	+ 78.0					
IPC bond strength, kp.-cm./sec.	In	3.24	4.04	+ 24.7	5.51	+ 70.1					
	Cross	1.68	2.26	+ 34.5	2.64	+ 57.1					
Porosity, sec./100 cc.		29	136	+369.0	64	+120.7					
Bendtsen smoothness, ml./min.		616	919	+ 49.2	498	- 19.2					
Cobb size, g./sq. m.		36.5	35.8	- 1.9	36.6	+ 0.3					

[a] Based on US liner results as reference.

[b] Average of single and double face results for A- and B-flute.

TABLE XXVIII

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 50% R.H.

(41.0-42.0-lb.)

Test Property[b]		US Liner	EG Liner	Diff.,[a] %	SC Liner	Diff., %	US Liner	EG Liner	Diff., %	Liner	Diff., %
							Unit Weight Basis				
ts weight, lb./M sq. ft.		42.8	41.6	- 2.8	39.6	- 7.5	--	--	--	--	--
iper, pt.		12.1	11.6	- 4.1	12.0	- 0.8	--	--	--	--	--
arent density		3.6	3.6	0.0	3.2	- 11.1	--	--	--	--	--
sting strength, p.s.i.g.		115	146	+ 27.0	137	+ 19.1	2.69	3.51	+ 30.5	3.46	+ 28.6
endorf tear, g./sheet	In	292	289	- 1.0	264	- 9.6	6.82	6.95	+ 1.9	6.67	- 2.2
	Cross	364	353	- 3.0	313	- 14.0	8.50	8.49	- 0.1	7.90	- 7.1
	Av.	328	321	- 2.1	288	- 12.2					
ion tear, in.-oz.	In	70	59	- 15.7	62	- 11.4	1.64	1.42	- 13.4	1.57	- 4.3
	Cross	86	72	- 16.3	67	- 22.1	2.01	1.73	- 13.9	1.69	- 15.9
	Av.	78	66	- 15.4	65	- 16.7					
ture, unit	In	32	31	- 3.1	28	- 12.5	0.75	0.75	0.0	0.71	- 5.3
	Cross	32	32	0.0	28	- 12.5	0.75	0.77	+ 2.7	0.71	- 5.3
	Av.	32	32	0.0	28	- 12.5					
ied ring compression, lb./in.	In	19.3	22.6	+ 17.1	20.8	+ 7.8	0.45	0.54	+ 20.0	0.53	+ 17.8
	Cross	15.4	16.6	+ 7.8	16.0	+ 3.9	0.36	0.40	+ 11.1	0.40	+ 11.1
stiffness, g.-cm.	In	68	78	+ 14.7	84	+ 23.5					
	Cross	23	30	+ 30.4	27	+ 17.4					
le, lb./in.	In	95.2	125.4	+ 31.7	126.4	+ 32.8	2.22	3.01	+ 35.6	3.19	+ 43.7
	Cross	32.9	50.7	+ 54.1	46.4	+ 41.0	0.77	1.22	+ 58.4	1.17	+ 51.9
h, %	In	2.2	1.8	- 18.2	2.0	- 9.1					
	Cross	3.8	3.4	- 10.5	4.7	+ 23.7					
s of elasticity, i. x 10^3	In	771	1060	+ 37.5	943	+ 22.3					
	Cross	300	454	+ 51.3	331	+ 10.3					
in.-lb./sq. in.	In	1.36	1.51	+ 11.0	1.55	+ 14.0					
	Cross	0.95	1.22	+ 28.4	1.59	+ 67.4					
d strength, kp.-cm./sec.	In	4.76	4.29	- 9.9	5.86	+ 23.1					
	Cross	2.27	2.39	+ 5.3	2.58	+ 13.7					
y, sec./100 cc.		28	109	+289.3	66	+135.7					
n smoothness, ml./min.		700	954	+ 36.6	1042	+ 49.0					
ze, g./sq. m.		33.2	32.4	- 2.4	37.0	+ 11.4					

on US liner results as reference.

ge of single and double face results for A- and B-flute.

TABLE XXIX

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 65% R H

(25.6-26.0-lb)

Test Property[b]	US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %[a]	US Liner	EG Liner	Diff., %[a]	SC Liner	Diff., %[a]
						Unit Weight Basis				
Weight, lb /M sq ft	28.2	27.4	-2.8	27.0	-4.3	--	--	--	--	--
Caliper, pt	10.0	8.0	-20.0	8.0	-20.0	--	--	--	--	--
Apparent density	2.8	3.4	+21.4	3.4	+21.4	--	--	--	--	--
Bursting strength, p s i g	70	96	+37.1	107	+52.9	2.48	3.50	+41.1	3.96	+59.7
Elmendorf tear, g /sheet										
In	228	188	-17.5	160	-29.8	8.09	6.86	-15.2	5.93	-26.7
Cross	284	228	-19.7	209	-26.4	10.07	8.32	-17.4	7.74	-23.1
Av	250	208	-16.8	184	-26.4					
Torsion tear, in -oz										
In	58	52	-10.3	53	-8.6	2.06	1.90	-7.8	1.96	-4.9
Cross	68	57	-16.2	62	-8.8	2.41	2.08	-13.7	2.30	-4.6
Av	62	54	-12.9	58	-6.5					
Puncture, unit										
In	20	18	-10.0	16	-20.0	0.71	0.66	-7.0	0.59	-16.9
Cross	20	19	-5.0	16	-20.0	0.71	0.69	-2.8	0.59	-16.9
Av	20	19	-5.0	16	-20.0					
Mod ring compression, lb /in										
In	15.4	15.9	+3.2	16.6	+7.8	0.55	0.58	+5.5	0.61	+10.9
Cross	10.8	10.6	-1.9	10.9	+0.9	0.38	0.39	+2.6	0.40	+5.3
Taber stiffness, g -cm										
In	25	20	-20.0	22	-12.0					
Cross	10	6	-40.0	7	-30.0					
Tensile, lb /in										
In	52.8	75.4	+42.8	87.8	+66.3	1.87	2.75	+47.1	3.25	+73.8
Cross	20.8	29.8	+43.3	25.3	+21.6	0.74	1.09	+47.3	0.94	+27.0
Stretch, %										
In	2.0	2.0	0.0	2.4	+20.0					
Cross	3.8	5.0	+31.6	5.6	+47.4					
Mod of elasticity, p s i 10^3										
In	590	932	+58.0	953	+61.5					
Cross	239	333	+39.3	284	+18.8					
T E A , in -lb /sq in										
In	0.74	0.93	+32.4	1.30	+75.7					
Cross	0.60	1.04	+73.3	1.06	+76.7					
IPC bond strength, kp.-cm./sec										
In	1.96	1.78	-9.2	1.98	+1.0					
Cross	1.85	1.67	-9.7	1.92	+3.8					
Porosity, sec /100 cc	10	22	+120.0	32	+222.0					
Bendtsen smoothness, ml /min	1108	803	-27.1	763	-31.1					
Cobb size, g /sq m	33.6	32.9	-2.1	33.8	+0.6					

[a] Based on US liner results as reference
[b] Average of single and double face results for A- and B-flute

TABLE XXX

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 65% R H

(30 7-33 0-lb)

Test Property[b]		US Liner	EG Liner	Diff , %[a]	SC Liner	Diff., %[a]	US Liner	EG Liner	Diff , %[a]	SC Liner	Diff , %[a]
							Unit Weight Basis				
Weight, lb /M sq ft		35 7	32 4	-9 2	31 5	-11.8	--	--	--	--	--
Caliper, pt		10 0	8 8	-12 0	9 9	-1 0	--	--	--	--	--
Apparent density		3 6	3 6	0 0	3 2	-11 1	--	--	--	--	--
Bursting strength, p s i.g		104	123	+18 3	116	+11 5	2.91	3 80	+30 6	3 68	+26.5
Elmendorf tear, g /sheet											
	In	270	226	-16.3	251	-7 0	7 56	6.98	-7 7	7 97	+5 4
	Cross	342	284	-17.0	274	-19 9	9 58	8 77	-8.5	8.70	-9 2
	Av.	306	255	-16.7	262	-14.4					
Torsion tear, in - oz											
	In	68	54	-20 6	64	-5 9	1 90	1 67	-12 1	2 03	+6 8
	Cross	85	68	-20 0	62	-27 1	2 38	2 10	-11.8	1 97	-17 2
	Av	76	62	-18 4	62	-18 4					
Puncture, unit											
	In	25	22	-12 0	22	-12 0	0 70	0 68	-2.9	0 70	0 0
	Cross	26	22	-15 4	22	-15 4	0 73	0 68	-6 8	0 70	-4 1
	Av	26	22	-15 4	22	-15 4					
Mod ring compression, lb /in											
	In	23 2	21 6	-6 9	20 0	-13 8	0 65	0 67	+3 1	0 63	-3.1
	Cross	14 9	14.2	-4 7	14 0	-6 0	0 42	0.44	+4 8	0 44	+4 8
Taber stiffness, g -cm											
	In	38	38	0 0	42	+10 5					
	Cross	14	12	-14 3	14	0 0					
Tensile, lb /in											
	In	81 5	99 4	+22.0	91 0	+11 7	2 28	3 07	+34 6	2 89	+26 8
	Cross	28 2	36 3	+28.7	37 6	+33 3	0 79	1 12	+41 8	1 19	+50 6
Stretch, %	In	2 4	2 0	-16 7	2 0	-16 7					
	Cross	4 2	4 8	+14 3	5 7	+35 7					
Mod of elasticity, p s i $x10^3$											
	In	814	1080	+32 7	860	+5 7					
	Cross	316	376	+19 0	308	-2 5					
T E A , in -lb /sq in											
	In	1 29	1 32	+2 3	1 14	-11 6					
	Cross	0 92	1 24	+34 8	1 48	+60 9					
IGT bond strength, kp.-cm./sec											
	In	2 17	2 13	-1 8	2 29	+5 5					
	Cross	1 89	2 12	+12 2	2 24	+18 5					
Porosity, sec /100 cc		31	125	+303 2	21	-32 3					
Bendtsen smoothness, ml /min.		606	907	+49 7	874	+44 2					
Cobb size, g /sq m		33 0	39 2	+18 8	34 4	+4 2					

[a] Based on US liner results as reference
[b] Average of single and double face results for A- and B-flute

TABLE XXXI

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 65% R H

(35 8-38.0-lb)

Test Property[b]		US Liner	EG Liner	Diff, %[a]	SC Liner	Diff, %[a]	US Liner	EG Liner	Diff, %[a]	SC Liner	Diff, %[a]
							Unit Weight Basis				
Weight, lb /M sq ft		40 0	38 1	-4 8	37 5	-6 2	--	--	--	--	--
Caliper, pt		11 4	10 4	-8 8	10 2	-10 5	--	--	--	--	--
Apparent density		3 6	3 7	+2 8	3.7	+2 8	--	--	--	--	--
Bursting strength, p s i g		98	135	+37.8	137	+39 8	2 45	3.54	+44 5	3.65	+49 0
Elmendorf tear, g /sheet	In	308	285	-7 5	282	-8 4	7.70	7.48	-2 9	7.52	-2.3
	Cross	387	348	-10 1	324	-16 3	9 68	9 13	-5 7	8.64	-10 7
	Av	348	317	-8.9	302	-13.2					
Torsion tear, in.-oz	In	77	62	-19 5	76	-1 3	1 92	1 63	-15.1	2 03	+5 7
	Cross	94	75	-20 2	82	-12.8	2.35	1.97	-16 2	2.19	-6 8
	Av.	85	70	-17 6	80	-5.9					
Puncture, unit	In	30	28	-6 7	26	-13 3	0 75	0.73	-2 7	0 69	-8 0
	Cross	31	28	-9 7	26	-16 1	0.78	0.73	-6 4	0.69	-11.5
	Av	30	28	-6.7	26	-13 3					
Mod ring compression, lb /in	In	23 7	24 6	+3.8	23.3	-1 7	0.59	0.65	+10.2	0 62	+5 1
	Cross	14 6	16 6	+13 7	16 0	+9.6	0 36	0.44	+22 2	0 43	+19 4
Taber stiffness, g.-cm.	In	52	54	+3 8	48	-7 7					
	Cross	16	20	+25 0	17	+6 2					
Tensile, lb /in	In	80 4	108 7	+35 2	103 0	+28 1	2.01	2 85	+41 8	2 75	+36 8
	Cross	27 0	44 8	+65 9	43 8	+62 2	0.68	1.18	+73 5	1 17	+72 1
Stretch, %	In	2 2	2 0	-9 1	2.4	+9 1					
	Cross	5 1	3 8	-25 5	6 0	+17 6					
Mod of elasticity, p.s i x10^3	In	729	1044	+43 2	899	+23.3					
	Cross	246	416	+69 1	338	+37 4					
T E A , in -lb /sq in	In	1 19	1 36	+14.3	1 64	+37 8					
	Cross	1 06	1 18	+11.3	1 83	+72 6					
IPC bond, strength, kp.-cm./sec.	In	1 92	1 90	-1 0	2 28	+18 8					
	Cross	1 89	1 92	+1 6	1 98	+4.8					
Porosity, sec /100 cc		28	110	+292 9	55	+96 4					
Bendtsen smoothness, ml /min		666	912	+36 9	450	-32 4					
Cobb size, g /sq m		32 7	32 0	-2 1	32 0	-2 1					

[a]Based on US liner results as reference
[b]Average of single and double face results for A- and B-flute

TABLE XXXII

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC LINERBOARDS AT 65% R H

(41 0-42 0-lb)

st Property[b]		US Liner	EG Liner	Diff, %[a]	SC Liner	Diff., %[a]	US Liner	EG Liner	Diff, %[a]	SC Liner	Diff, %[a]
							Unit Weight Basis				
›ht, lb /M sq ft		43.7	42 4	-3 0	40 0	-8 5	--	--	--	--	--
ɪper, pt		12 4	11 8	-4 8	12 4	0.0	--	--	--	--	--
ɪrent density		3 5	3 6	+2 9	3 2	-8 6	--	--	--	--	--
›ting strength, p s i g		113	144	+27 4	142	+25 7	2 59	3 40	+31 3	3 55	+37 1
›ndorf tear, g /sheet											
	In	326	324	-0 6	303	-7 1	7.46	7.64	+2.4	7 58	+1 6
	Cross	401	384	-4 2	350	-12 7	9 18	9 06	-1 3	8 75	-4 7
	Av	364	354	-2 7	327	-10 2					
ion tear, in -oz											
	In	83	70	-14 6	76	-7 3	1 88	1.65	-12 2	1 90	+1 1
	Cross	104	88	-15 4	80	-23 1	2 38	2 08	-12 6	2 00	-16 0
	Av	93	78	-16 1	78	-16 1					
ture, unit											
	In	34	34	0 0	30	-11 8	0 78	0 80	+2 6	0 75	-3 8
	Cross	34	34	0.0	30	-11 8	0 78	0 80	+2 6	0 75	-3 8
	Av	34	34	0 0	30	-11 8					
ring compression, lb /in											
	In	20 8	22 5	+8 2	21 0	+1 0	0 48	0 53	+10 4	0 53	+10 4
	Cross	15 8	17 6	+11 4	16 2	+2 5	0 36	0 42	+16 7	0 40	+11 1
ı stiffness, g -cm											
	In	68	82	+20 6	87	+27 9					
	Cross	24	30	+25 0	25	+4 2					
ile, lb /in											
	In	89 5	115 6	+29 2	117 2	+30 9	2 05	2 75	+35 2	2 95	+42 9
	Cross	31 2	48 4	+55 1	42 8	+37 2	0 71	1 14	+60 6	1 07	+50 7
tch, %	In	2 4	2 0	-16 7	2 1	-12 5					
	Cross	4 2	3 8	-9 5	5 1	+21 4					
of elasticity, p ı x10³											
	In	724	993	+37 2	870	+20 2					
	Cross	269	403	+49 8	290	+7 8					
, in.-lb /sq in											
	In	1 58	1 46	+5 8	1 54	+11 6					
	Cross	1 02	1 28	+25 5	1 56	+52 9					
bond strength, kp -cm /sec											
	In	2 12	2 02	-4 7	2 50	+17 9					
	Cross	1 85	2 01	+8 6	2 18	+17 8					
ity, sec /100 cc		25	100	+300 0	59	+136 0					
n smoothness, ml /min		692	987	+42 6	1070	+54 6					
ion, g /sq m		28 8	28 7	-0 3	33 5	+16 3					

d on US liner results as reference
age of single and double face results for A- and B-flute

TABLE XXXIII

COMPARISON OF PHYSICAL CHARACTERISTICS OF DOMESTIC AND EUROPEAN LINERBOARDS
(50% Relative Humidity)

Test Property	US Liner 26-lb.	Difference,[a] % EUR. 25.6-lb. EG	Difference,[a] % EUR. 25.6-lb. SC	US Liner 33-lb.	Difference,[a] % EUR. 30.7-lb. EG	Difference,[a] % EUR. 30.7-lb. SC	US Liner 38-lb.	Difference,[a] % EUR. 35.8-lb. EG	Difference,[a] % EUR. 35.8-lb. SC	US Liner 42-lb.	Difference,[a] % EUR. 41.0-lb. EG	Difference,[a] % EUR. 41.0-lb. SC
Weight, lb./M sq. ft.	28.0	- 5.4	- 4.6	35.0	- 9.1	-11.4	39.4	- 5.1	- 7.6	42.8	- 2.8	- 7.5
Caliper, pt.	9.6	-18.8	-18.8	9.8	-10.2	- 1.0	11.2	-10.7	-11.6	12.1	- 4.1	- 0.8
Apparent density	3.0	+13.3	+13.3	3.6	0.0	-11.1	3.6	+ 5.6	+ 2.8	3.6	0.0	-11.1
Bursting strength, p.s.i.g.	72	+38.9(.01)	+47.2(.01)	105	+18.1(.01)	+ 6.7(.01)	98	+38.8(.01)	+38.8(.01)	115	+27.0(.01)	+19.1(.01)
factor	2.57	+46.7	+54.5	3.0	+30.0	+20.3	2.49	+46.2	+50.2	2.69	+30.5	28.6
Elmendorf tear, in-machine												
g./sheet	202	-17.8(.01)	-29.2(.01)	240	-17.9(.01)	-11.7(.01)	275	-10.5(.01)	-10.5(.01)	292	- 1.0(NS)	- 9.6(.01)
factor	7.21	-13.2	-25.7	6.86	- 9.8	- 0.3	6.98	- 5.7	- 3.2	6.82	+ 1.9	- 2.2
Elmendorf tear, cross-machine												
g./sheet	250	-18.4(.01)	-25.6(.01)	308	-18.2(.01)	-22.7(.01)	344	-11.3(.01)	-15.4(.01)	364	- 3.0(.01)	-14.0(.01)
factor	8.93	-13.8	-21.9	8.08	-10.0	-12.7	8.73	- 6.5	- 8.5	8.50	0.1	- 7.1
Average, in and cross	226	-18.6	-27.4	274	-17.9	-17.5	310	-11.0	-13.5	328	- 2.1	-12.2
Torsion tear, in-machine												
unit	50	-12.0	-10.0	60	-16.7	- 8.3	71	-29.6	- 9.9	70	-15.7	-11.4
factor	1.79	- 7.3	- 5.6	1.71	- 8.2	+ 3.5	1.80	-25.6	- 2.2	1.64	-13.4	- 4.3
Torsion tear, cross-machine												
unit	56	-14.3	- 7.1	74	-25.7	-29.7	83	-28.9	-21.7	86	-16.3	-22.1
factor	2.00	- 9.5	- 2.5	2.11	-18.0	-20.4	2.11	-25.1	-15.2	2.01	-13.9	-15.9
Average, unit	52	-11.5	- 7.7	66	-21.2	-19.7	77	-28.6	-16.9	78	-15.4	-16.7
Puncture, in-machine												
unit	20	-10.0	-20.0	24	-12.5	-16.7	28	- 7.1	- 7.1	32	- 3.1	-12.5
factor	0.71	- 4.2	-15.5	0.69	- 4.3	- 5.8	0.71	- 1.4	0.0	0.75	0.0	- 5.3
Puncture, cross-machine												
unit	20	-10.0	-20.0	24	- 8.3	-12.5	28	- 7.1	- 7.1	32	0.0	-12.5
factor	0.71	- 4.2	-15.5	0.67	0.0	- 1.4	0.71	- 1.4	0.0	0.75	+ 2.7	- 5.3
Average, unit	20	-10.0	-20.0	24	- 8.3	-16.7	28	- 7.1	- 7.1	32	0.0	-12.5
Modified ring compression,												
in-machine lb./in	16.0	+ 0.6(NS)	+ 8.8(.01)	23.4	- 8.1(.01)	-14.5(.01)	24.0	+ 2.5(.05)	- 4.2(.01)	19.3	+17.1(.01)	+ 7.8(.01)
factor	0.57	+ 7.0	+14.0	0.67	+ 1.5	- 3.0	0.61	+ 8.2	+ 3.3	0.45	+20.0	+17.8
cross-machine lb./in.	11.4	- 0.9(NS)	+ 2.6(.01)	16.0	- 5.0(.01)	-11.2(.01)	15.6	+14.1(.01)	+ 5.8(.01)	15.4	+ 7.8(.01)	+ 3.9(.01)
factor	0.41	+ 4.9	+ 7.3	0.46	+ 4.3	0.0	0.40	+20.0	+12.5	0.36	+11.1	+11.1

TABLE XXVIII (Continued)

COMPARISON OF PHYSICAL CHARACTERISTICS OF DOMESTIC AND EUROPEAN LINERBOARDS
(50% Relative Humidity)

Test Property		US Liner 26-lb	Difference,[a] % EUR 25.6-lb EG	Difference,[a] % EUR 25.6-lb SC	US Liner 33-lb	Difference,[a] % EUR 30.7-lb EG	Difference,[a] % EUR 30.7-lb SC	US Liner 38-lb	Difference,[a] % EUR 35.8-lb EG	Difference,[a] % EUR 35.8-lb SC	US Liner 42-lb	Difference,[a] % EUR 41.0-lb EG	Difference,[a] % EUR 41.0-lb SC
Taber stiffness, in-machine	g-cm	26	-23.1 (.01)	-15.4 (.01)	40	-7.5 (.01)	+5.0 (.01)	53	0.0 (NS)	-9.4 (.01)	68	+14.7 (.01)	+23.5 (.01)
	factor	0.93	-19.4	-11.8	1.14	+1.8	+18.4	1.35	+5.2	-2.2	1.59	+18.2	+33.5
Taber stiffness, cross-machine	g-cm	10	-20.0 (.01)	-20.0 (.01)	14	-7.1 (.01)	0.0 (NS)	16	+31.2 (.01)	+12.5 (.01)	23	+30.4 (.01)	+17.4 (.01)
	factor	0.36	-16.7	-16.7	0.40	+2.5	+12.5	0.41	+36.6	+19.5	0.54	+33.3	+25.9
Tensile strength, in-machine	lb/in	57.0	+39.6	+57.5	86.6	+23.6	+13.2	86.0	+35.8	+29.1	95.2	+31.7	+32.8
	factor	2.04	+47.1	+64.7	2.47	+36.0	+27.9	2.18	+43.1	+39.9	2.22	+35.6	+43.7
Tensile strength, cross-machine	lb/in	22.2	+37.8	+18.9	30.2	+25.2	+29.8	28.9	+63.3	+58.5	32.9	+54.1	+41.0
	factor	0.79	+45.6	+25.3	0.86	+38.4	+46.5	0.73	+72.6	+72.6	0.77	+58.4	+51.9
Stretch, %	in-machine	1.8	+5.6	+22.2	2.2	-9.1	-13.6	2.0	-10.0	+15.0	2.2	-18.2	-9.1
	cross-machine	3.1	+45.2	+58.1	3.6	+19.4	+41.7	4.4	-22.7	+22.7	3.8	-10.5	+23.7
Modulus of elasticity, psi x 10^3	in-machine	647	+52.9	+60.7	870	+33.8	+3.1	782	+42.5	+22.8	771	+37.5	+22.3
	cross-machine	271	+35.1	+18.3	354	+20.9	-2.3	279	+68.5	+35.5	300	+51.3	+10.3
[illegible] in-lb/in^2	[illegible]	[illegible]	+33.[illegible]	[illegible]	[illegible]	+8.1	-4.8	1.14	+19.3	+44.7	1.36	+11.[illegible]	+14.0
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+18.2	[illegible]	+15.0	[illegible]	0.95	+23.[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+23.[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28	+289.3	-35.7
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+40.2	-19.2	700	+36.6	+49.0
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE XXXIV

COMPARISON OF PHYSICAL CHARACTERISTICS OF DOMESTIC AND EUROPEAN LINERBOARDS
(65% Relative Humidity)

Test Property	US Liner 26-lb	Difference,[a] % EUR 25.6-lb EG	SC	US Liner 33-lb	Difference,[a] % EUR 30.7-lb EG	SC	US Liner 38-lb	Difference,[a] % EUR 35.8-lb EG	SC	US Liner 42-lb	Difference,[a] % EUR 41.0-lb EG	SC
Weight, lb/M sq ft	28.2	-2.8	-4.3	35.7	-9.2	-11.8	40.0	-4.8	-6.2	43.7	-3.8	-8.5
Caliper, pt	10.0	-20.0	-20.0	10.0	-12.0	-1.0	11.4	-8.8	-10.5	12.4	-4.8	0.0
Apparent density	2.8	+21.4	+21.4	3.6	0.0	-11.1	3.6	+2.8	+2.8	3.5	+2.9	-8.6
Bursting strength, p.s.i.g.	70	+37.1	+52.9	104	+18.3	+11.5	98	+37.8	+39.8	113	+27.4	+25.7
factor	2.48	+41.1	+59.7	2.91	+30.6	+26.5	2.45	+44.5	+49.0	2.59	+31.3	+37.1
Elmendorf tear, in-machine												
g./sheet	228	-17.5	-29.8	270	-16.3	-7.0	308	-7.5	-8.4	326	-0.6	-7.1
factor	8.09	-15.2	-26.7	7.56	-7.7	+5.4	7.70	-2.9	-2.3	7.46	+2.4	+1.6
Elmendorf tear, cross-machine												
g./sheet	284	-19.7	-26.4	342	-17.0	-19.9	387	-10.1	-16.3	401	-4.2	-12.7
factor	10.07	-17.4	-23.1	9.58	-8.5	-9.2	9.68	-5.7	[illegible]	9.18	-1.3	-4.7
Average, in and cross	250	-16.8	-26.4	306	-16.7	-14.4	348	-8.9	-13.2	364	-2.7	-10.2
Torsion tear, in-machine												
unit	58	-10.3	-8.6	68	-20.6	-5.9	77	-19.5	-1.3	83	-14.6	-7.3
factor	2.06	-7.8	-4.9	1.90	-12.1	+6.8	1.92	-15.1	+5.7	1.88	-12.2	+1.1
Torsion tear, cross-machine												
unit	68	-16.2	-8.8	85	-20.0	-27.1	94	-20.2	-12.8	104	-15.4	-23.1
factor	2.41	-13.7	-4.6	2.38	-11.8	-17.2	2.35	-16.2	-6.8	2.38	-12.6	-16.0
Average, unit	62	-12.9	-6.5	76	-18.4	-18.4	85	-17.6	-5.9	93	-16.1	-16.1
Puncture, in-machine												
unit	20	-10.0	-20.0	25	-12.0	-12.0	30	-6.7	-13.3	34	0.0	-11.8
factor	0.71	-7.0	-16.9	0.70	-2.9	0.0	0.75	-2.7	-8.0	0.78	+2.6	-3.8
Puncture, cross-machine												
unit	20	-5.0	-20.0	26	-15.4	-15.4	31	-9.7	-16.1	34	0.0	-11.8
factor	0.71	-2.8	-16.9	0.73	-6.8	-4.1	0.78	-6.4	-11.5	0.78	+2.6	-3.8
Average, unit	20	-5.0	-20.0	26	-15.4	-15.4	30	-6.7	-13.3	34	0.0	-11.8
Modified ring compression,												
in-machine lb./in.	15.4	+3.2	+7.8	23.2	-6.9	-13.8	23.7	+3.8	-1.7	20.8	+8.2	+1.0
factor	0.55	+5.5	+10.9	0.65	+3.1	-3.1	0.59	+10.2	+5.1	0.48	+10.4	+10.4
cross-machine lb./in.	10.8	-1.9	+0.9	14.9	-4.7	-6.0	14.6	+13.7	+9.6	15.8	+11.4	+2.5
factor	0.38	+2.6	+5.3	0.42	+4.8	+4.8	0.36	+22.2	+19.4	0.36	+16.7	+11.1

TABLE XXXIV (Continued)

COMPARISON OF PHYSICAL CHARACTERISTICS OF DOMESTIC AND EUROPEAN LINERBOARDS
(65% Relative Humidity)

Test Property		US Liner 26-lb.	Difference,[a] % EUR. 25.6-lb. EG	SC	US Liner 33-lb.	Difference,[a] % EUR. 30.7-lb. EG	SC	US Liner 38-lb.	Difference,[a] % EUR. 35.8-lb. EG	SC	US Liner 42-lb.	Difference,[a] % EUR. 41.0-lb. EG	SC
:aber stiffness, in-machine	g.-cm.	25	- 20.0	- 12.0	38	0.0	+ 10.5	52	+ 3.8	- 7.7	68	+ 20.6	+ 27.9
	factor	0.89	- 18.0	- 9.0	1.06	+ 10.4	+ 25.5	1.30	+ 9.2	- 1.5	1.56	+ 23.7	+ 39.7
Taber stiffness, cross-Machine	g.-cm.	10	- 40.0	- 30.0	14	- 14.3	0.0	16	+ 25.0	+ 6.2	24	+ 25.0	+ 4.2
	factor	0.35	- 37.1	- 25.7	0.39	- 5.1	+ 12.8	0.40	+ 30.0	+ 12.5	0.55	+ 29.1	+ 12.7
ensile strength, in-machine	lb./in.	52.8	+ 42.8	+ 66.3	81.5	+ 22.0	+ 11.7	80.4	+ 35.2	+ 28.1	89.5	+ 29.2	+ 30.9
	factor	1.87	+ 47.1	+ 73.8	2.28	+ 34.6	+ 26.8	2.01	+ 41.8	+ 36.8	2.05	+ 33.2	+ 42.9
'nsile strength, cross-machine	lb./in.	20.8	+ 43.3	+ 21.6	28.2	+ 28.7	+ 33.3	27.0	+ 65.9	+ 62.2	31.2	+ 55.1	+ 37.2
	factor	0.74	+ 47.3	+ 27.0	0.79	+ 41.8	+ 50.6	0.68	+ 73.5	+ 72.1	0.71	+ 60.6	+ 50.7
retch, %	in-machine	2.0	0.0	+ 20.0	2.4	- 16.7	- 16.7	2.2	- 9.1	+ 9.1	2.4	- 16.7	- 12.5
	cross-machine	3.8	+ 31.6	+ 47.4	4.2	+ 14.3	+ 35.7	5.1	- 25.5	+ 17.6	4.2	- 9.5	+ 21.4
dulus of elasticity, :.s.i. x 10^3	in-machine	590	+ 58.0	+ 61.5	814	+ 32.7	+ 5.7	729	+ 43.2	+ 23.3	724	+ 37.2	+ 20.2
	cross-machine	239	+ 39.3	+ 18.8	316	+ 19.0	- 2.5	246	+ 69.1	+ 37.4	269	+ 49.8	+ 7.8
:.A., in.-lb./sq. in.	in-machine	0.74	+ 32.4	+ 75.7	1.29	+ 2.3	- 11.6	1.19	+ 14.3	+ 37.8	1.38	+ 5.8	+ 11.6
	cross-machine	0.60	+ 73.3	+ 76.7	0.92	+ 34.8	+ 60.9	1.06	+ 11.3	+ 72.6	1.02	+ 25.5	+ 52.9
bond strength, kg-cm/sec.	in-machine	1.96	- 9.2	+ 1.0	217	- 1.8	+ 5.5	1.92	- 1.0	+ 18.8	2.12	- 4.7	+ 17.9
	cross-machine	1.85	- 9.7	+ 3.8	1.89	+ 12.2	+ 18.5	1.89	+ 1.6	+ 4.8	1.85	+ 8.6	+ 17.8
osity, sec./100 cc.		10	+120.0	+222.0	31	+303.2	- 32.3	28	+292.9	+ 96.4	25	+300.0	+136.0
:thness, ml./min.		1108	- 27.1	- 31.1	606	+ 49.7	+ 44.2	666	+ 36.9	- 32.4	692	+ 42.6	+ 54.6
size, g./sq. in.		33.6	- 2.1	+ 0.6	33.0	+ 18.8	+ 4.2	32.7	- 2.1	- 2.1	28.8	- 0.3	+ 16.3

.S. linerboard used as reference.

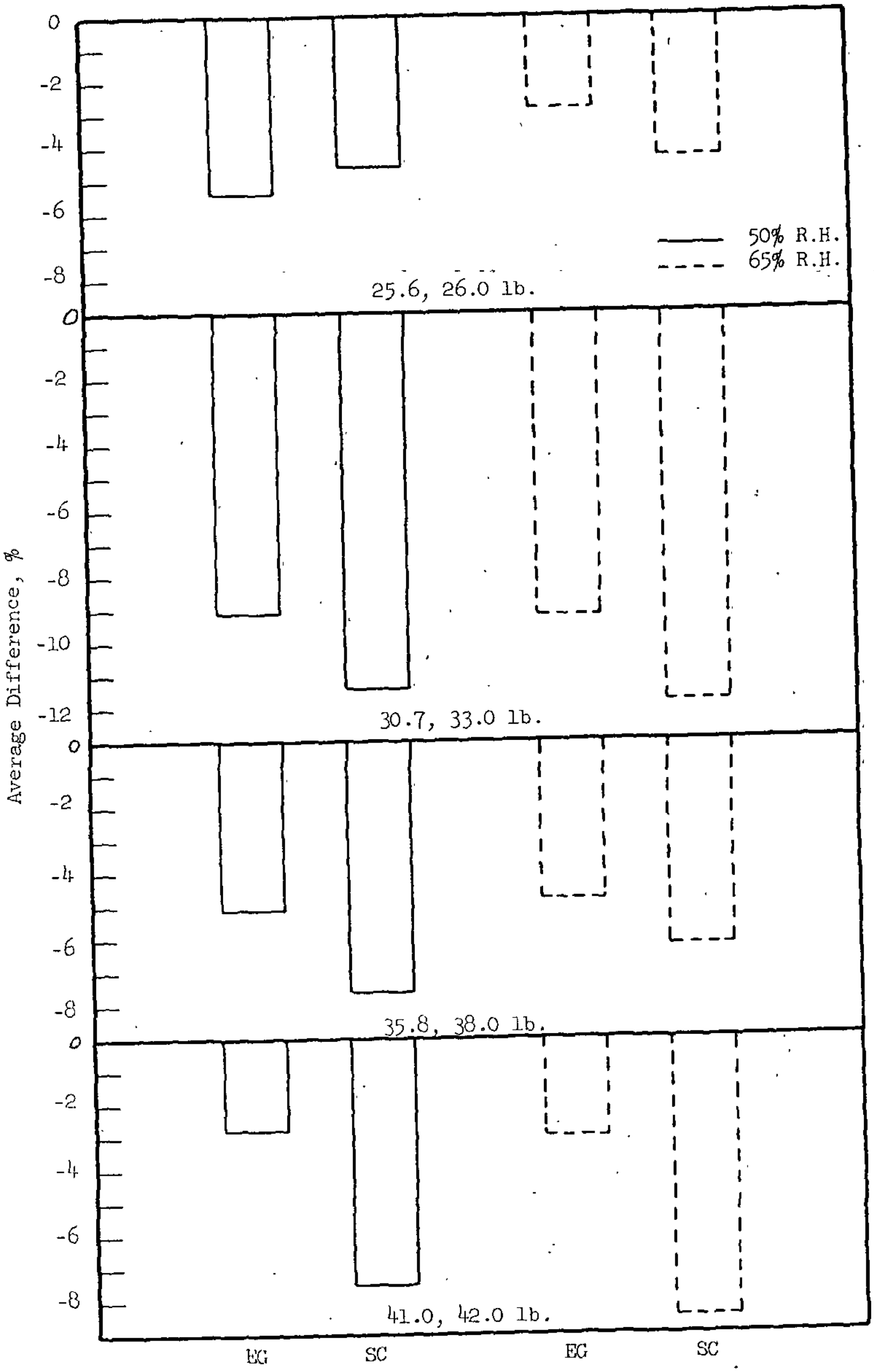


Figure 14. Comparison of Average Difference in Basis Weight of European and U.S. Linerboards

In view of the above relationship for basis weight, it is not surprising that the U.S. linerboards are higher in caliper (see Tables XXXIII and XXXIV) than the competitive European grade weights. The per cent differences in caliper follow and are illustrated in Fig. 15

Nominal Wt., lb./ M sq ft	Linerboard Caliper Difference, %[a] 50% R.H. U.S Linerboard Caliper, pt	E.G.	S.C	65% R.H U.S. Linerboard Caliper, pt.	E.G.	S.C.
26.0	9 6	-18.8	-18 8	10 0	-20.0	-20.0
33.0	9 8	-10 2	-1.0	10 0	-12.0	-1 0
38.0	11 2	-10.7	-11.6	11 4	-8.8	-10 5
42.0	12 1	-4 1	-0.8	12.4	-4 8	0.0

[a]U.S. linerboard results used as reference.

It may be seen that at all grade weight levels the U S. linerboards are in most cases significantly higher in caliper than the corresponding European linerboards The greatest difference is at the 25 6, 26.0-lb grade weight level and the least at the 41 0, 42 0-lb grade weight level In general, the caliper of the Svenska Cellulosa linerboards average slightly higher than the caliper of Enso Gutseit linerboards

It may be observed that the apparent densities (see Tables XXXIII and XXXIV) of the 26 0-lb and 38.0-lb. U.S. linerboards are lower than the corresponding European linerboards The densities of the 33 0-lb and 42.0-lb U S linerboards are approximately equal to the corresponding Enso Gutseit linerboards but approximately 8 to 11% higher than the competitive Svenska Cellulosa linerboards. The per cent differences at the four grade weights follow and are illustrated in Fig. 16

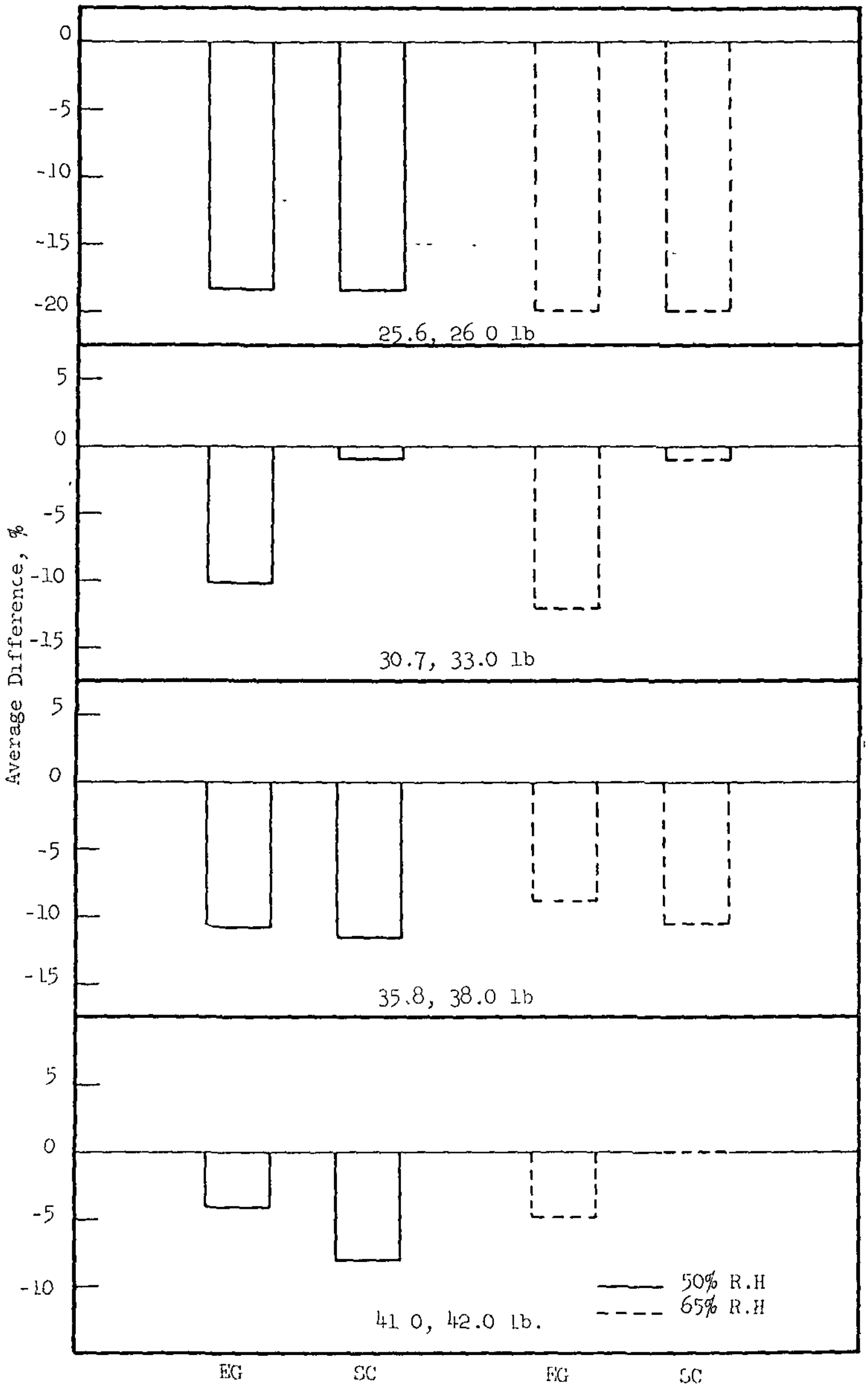


Figure 15. Comparison of Average Difference in Caliper of European and U.S. Linerboards

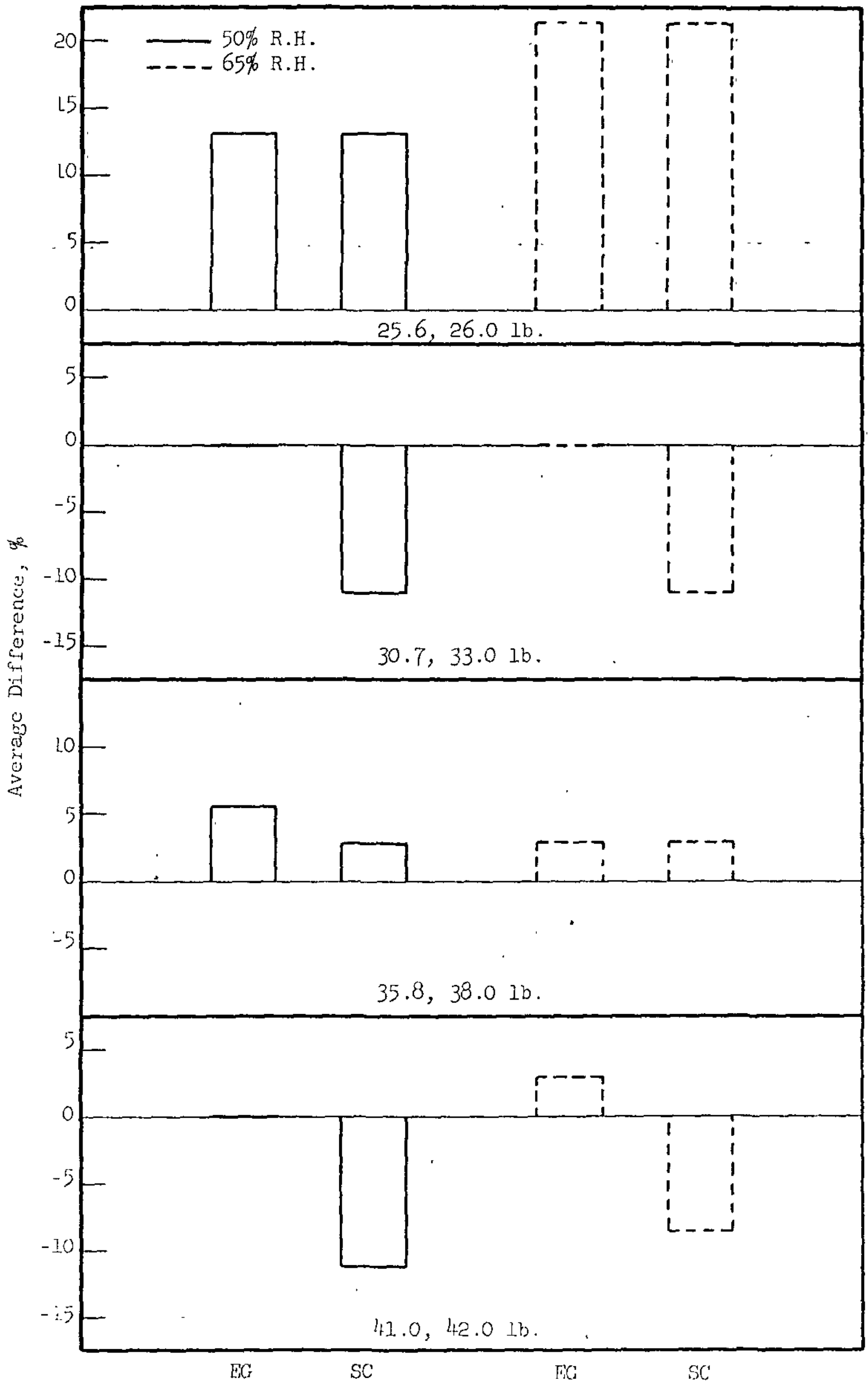


Figure 16. Comparison of Average Difference in Apparent Density
[illegible]

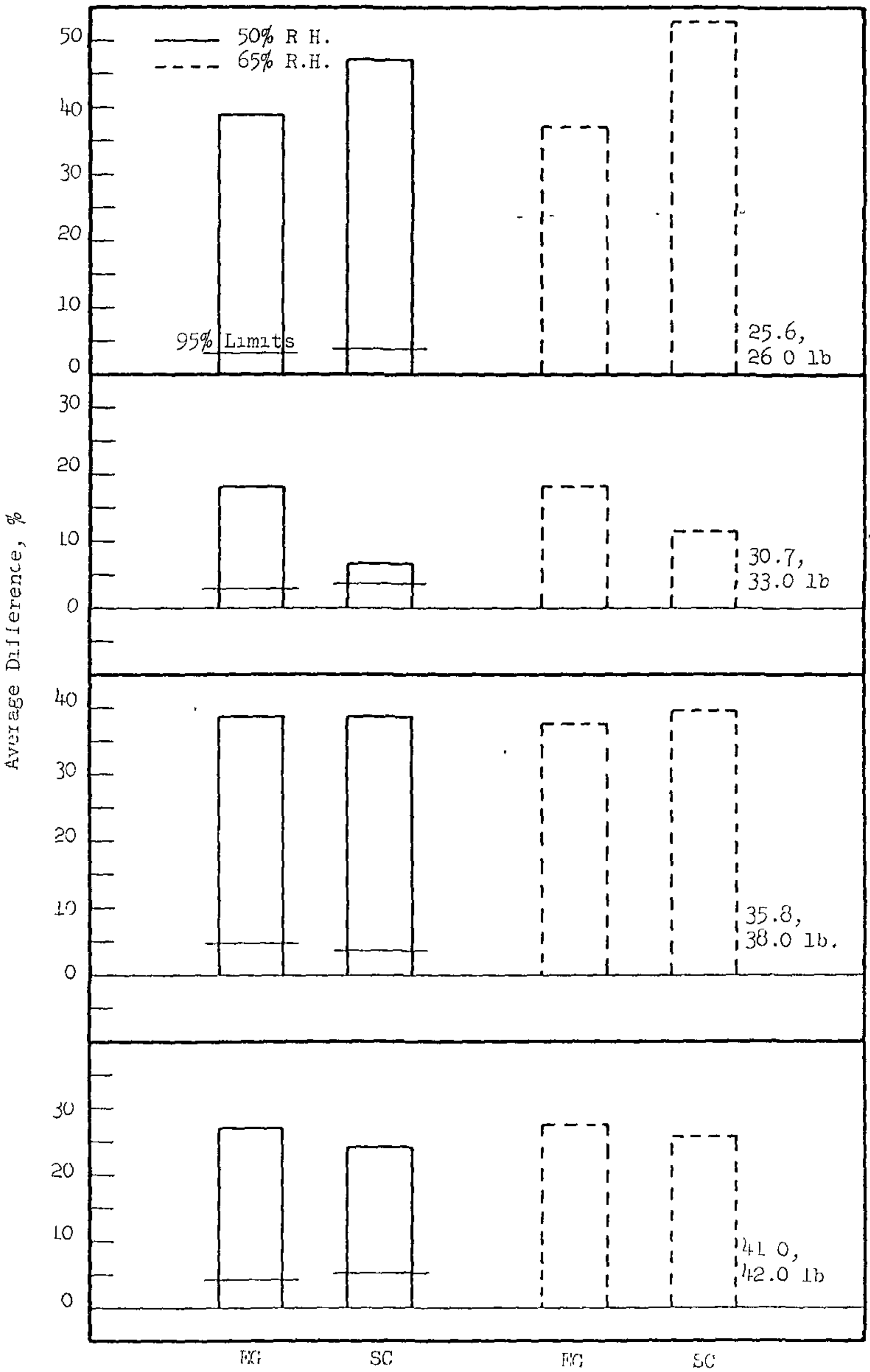
Nominal Wt., lb./M sq.ft.	Difference in Apparent Density, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard Apparent Density	E.G.	S.C.	U.S. Linerboard Apparent Density	E.G.	S.C.
26.0	3.0	+13.3	+13.3	2.8	+21.4	+21.4
33.0	3.6	0.0	-11.1	3.6	0.0	-11.1
38.0	3.6	+5.6	+2.8	3.6	+2.8	+2.8
42.0	3.6	0.0	-11.1	3.5	+2.9	-8.6

[a]U.S. linerboard results used as reference.

When the bursting strength (see Tables XXXIII and XXXIV) of the U.S. and European linerboards are considered it may be noted that the results for the U.S. linerboards are markedly lower than those for the corresponding European linerboards. The statistical significance of the average differences for a selected number of physical properties at 50% R.H. was determined by means of analysis of variance (see Appendix for procedure). The per cent difference in bursting strength at the four different grade weight levels are listed as follows (together with an indication of the significance of the difference - see figure in parentheses) and are graphically illustrated in Fig. 17:

Nominal Weight, lb./M sq.ft.	Bursting Strength Difference, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard Bursting Strength, p.s.i.	E.G.	S.C.	U.S. Linerboard Bursting Strength, p.s.i.	E.G.	S.C.
26.0	72	+38.9 (.01)	+47.2 (.01)	70	+37.1	+52.9
33.0	105	+18.1 (.01)	+6.7 (.01)	104	+18.3	+11.5
38.0	98	+38.8 (.01)	+38.8 (.01)	98	+37.8	+39.8
42.0	115	+27.0 (.01)	+19.1 (.01)	113	+27.4	+25.7
Average		+30.7	+38.0		+30.2	+32.5

[a]U.S. linerboard used as reference.

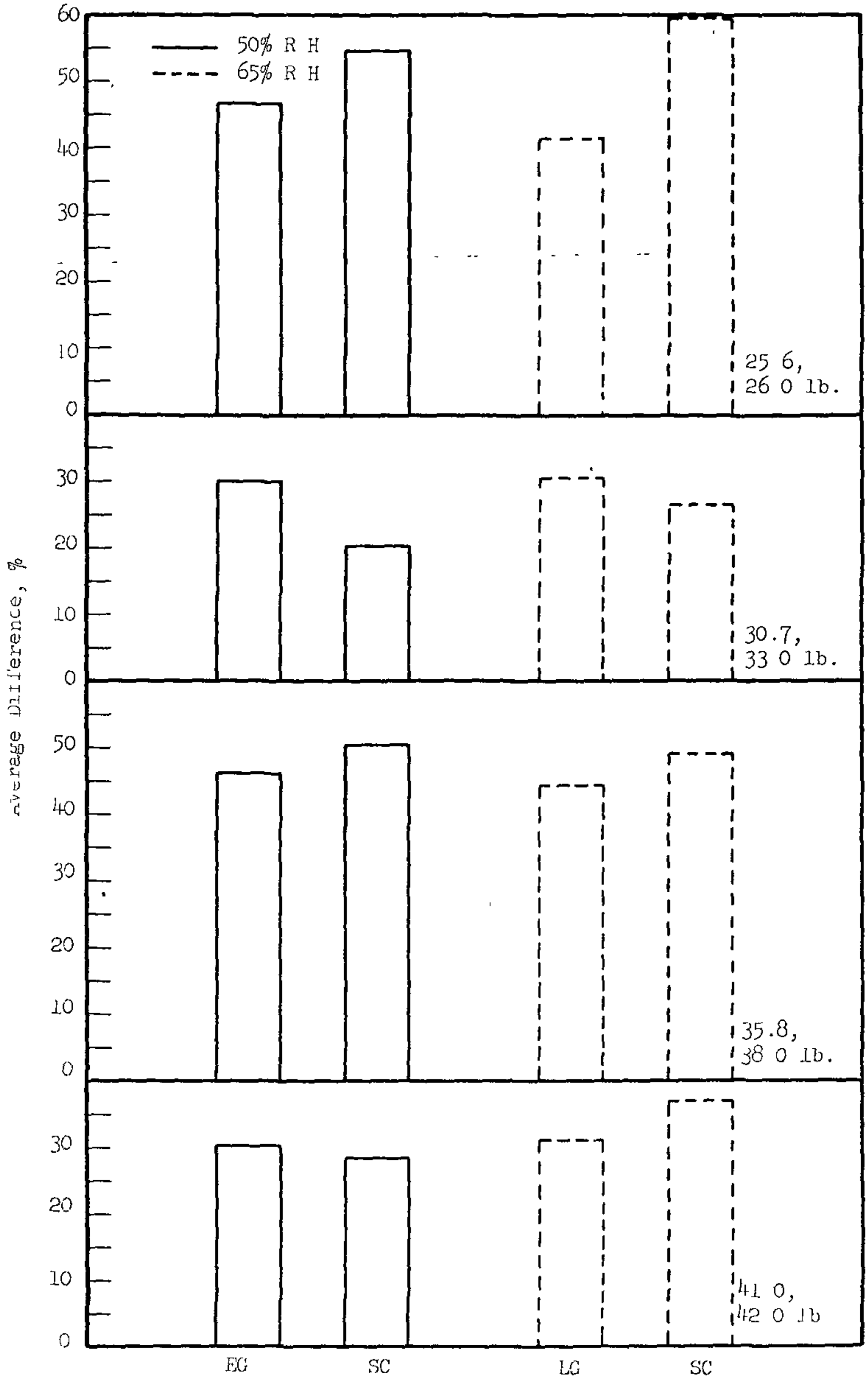

50% R H.
65% R.H.
95% Limits
25.6,
26 0 lb
30.7,
33.0 lb
35.8,
38.0 lb.
41 0,
42.0 lb
Average Difference, %
FG
SC
FG
SC

It may be seen that the greatest disparity in bursting strength is at the lowest grade weight level and the least at the 30.7, 33.0-lb. grade weight level. In general, the bursting strength results for the U.S. linerboards are approximately 30% lower than those for Enso Gutseit linerboards at corresponding grade weight levels, and 32 to 38% lower than those for Svenska Cellulosa linerboards. It may be noted that all the differences in bursting strength between U.S. and European linerboards are significant at the 1% confidence level. When the bursting strength results are compared in terms of bursting strength per pound of basis weight, it may be seen that the European linerboards are far more efficient (i.e., develop greater bursting strength per pound) than the U.S. linerboards as may be noted from the differences in bursting strength per pound of basis weight tabulated as follows and shown in Fig. 18:

	Difference in Bursting Strength per Unit Basis Weight, %[a]					
	50% R.H.			65% R.H.		
Nominal Wt., lb./M sq.ft.	U.S. Linerboard Bursting Strength, p.s.i./lb.	E.G.	S.C.	U.S. Linerboard Bursting Strength, p.s.i./lb.	E.G.	S.C.
26.0	2.57	+46.7	+54.5	2.48	+41.1	+59.7
33.0	3.00	+30.0	+20.3	2.91	+30.6	+26.5
38.0	2.49	+46.2	+50.2	2.45	+44.5	+49.0
42.0	2.69	+30.5	+28.6	2.59	+31.3	+37.1

[a]U.S. linerboard results used as reference.

The machine-direction Elmendorf tearing strength results are tabulated in Tables XXXIII and XXXIV and the per cent differences, together with the level of significance of the differences, are given as follows and also in Fig. 19:



Comparison of Average Difference in Bursting Strength

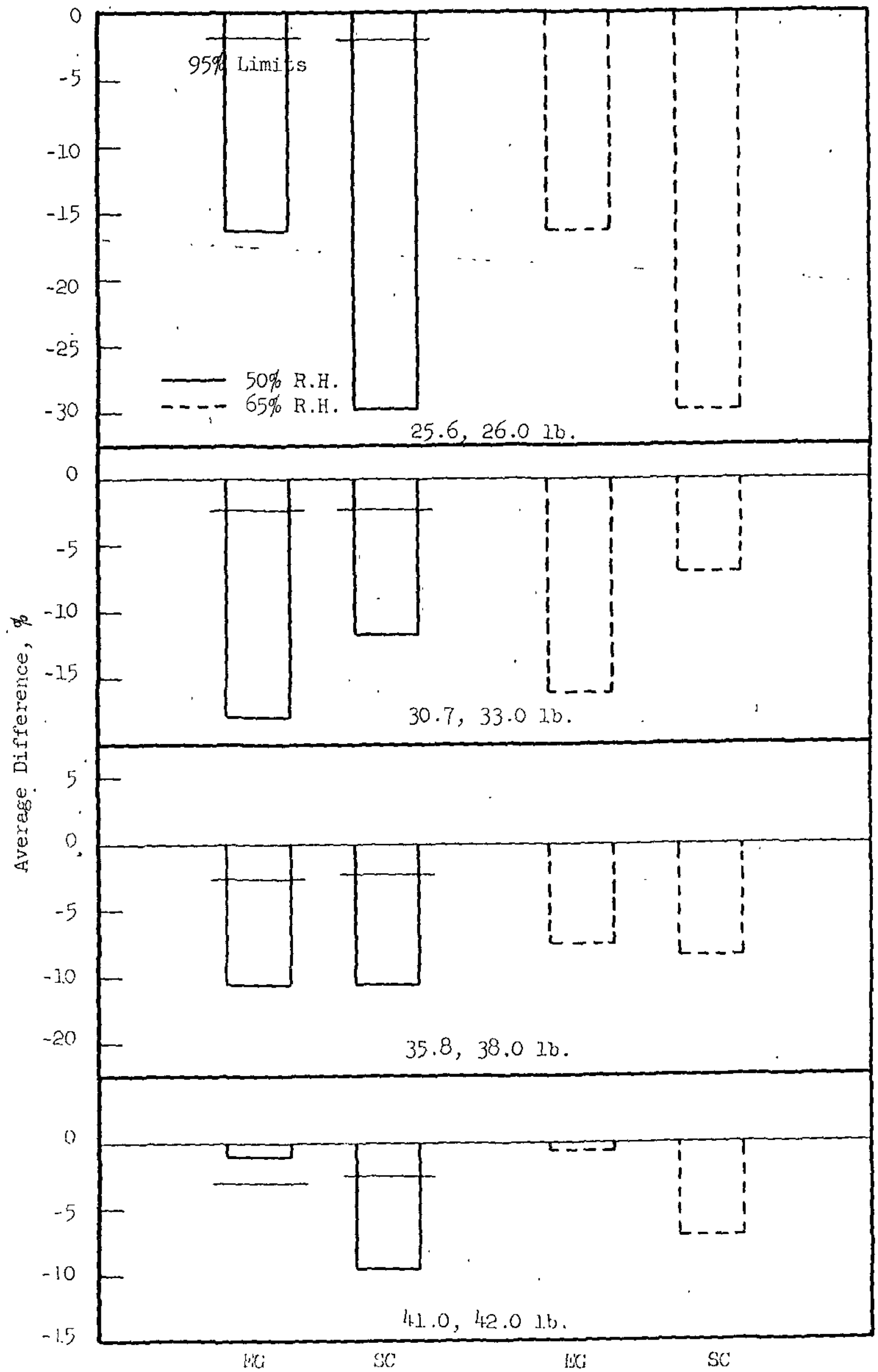


Figure 19. Comparison of Average Difference in Machine-Direction ~~[illegible]~~ of European and U.S. Linerboards

Nominal Wt., lb./M sq ft	Difference in Machine-Direction Tearing Strength, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard Tearing Strength, g./sheet	E.G.	S.C.	U.S. Linerboard Tearing Strength, g./sheet	E.G.	S.C.
26.0	202	-17.8 (.01)	-29.2 (.01)	228	-17.5	-29.8
33.0	240	-17.9 (.01)	-11.7 (.01)	270	-16.3	-7.0
38.0	275	-10.5 (.01)	-10.5 (.01)	308	-7.5	-8.4
42.0	292	-1.0 (.01)	-9.6 (.01)	326	-0.6	-7.1
	Average	-11.8	-15.5		-10.5	-13.1

[a]U.S. linerboard results used as reference.

It may be seen that in all cases the machine-direction tearing strengths of U.S. linerboards are higher than the tearing strengths of corresponding European linerboards — on an average basis, 10 to 12% higher than Enso Gutseit and 13 to 16% higher than Svenska Cellulosa linerboards. Further, all the differences are statistically significant. When the machine-direction tearing strengths are considered on a unit weight basis, the differences between U.S. and European linerboards are greatly reduced. however, in most instances the tearing strength factors are higher for the U.S. linerboards as may be seen from the differences in tearing strength factors tabulated as follows:

Nominal Wt., lb./M sq ft.	Difference in Machine-Direction Tearing Strength Factor, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard Tearing Strength Factor	E.G.	S.C.	U.S. Linerboard Tearing Strength Factor	E.G.	S.C.
26.0	7.21	-13.2	-25.7	8.09	-15.2	-26.7
33.0	6.86	-9.8	-0.3	7.56	-7.7	+5.4
38.0	6.98	-5.7	-3.2	7.70	-2.9	-2.5
42.0	6.82	+1.9	-2.2	7.46	+2.4	+1.6
	Average	-6.7	-7.9		-5.9	-5.5

[a]U.S. linerboard results used as reference.

The cross-machine tearing strengths of the U.S. linerboards are also higher (see Tables XXXIII and XXXIV) than the tearing strengths of the corresponding European linerboards as may be seen from the following average differences which are illustrated in Fig 20·

	Difference in Cross-Machine Tearing Strength, %[a]					
	50% R.H.			65% R H.		
Nominal Wt , lb./ M sq.ft.	U S. Linerboard C.D. Tearing Strength, g./sheet	E.G.	S.C.	U S. Linerboard C.D. Tearing Strength, g./sheet	E.G.	S.C.
26.0	250	-18 4 (.01)	-25.6 (.01)	284	-19.7	-26 4
33.0	308	-18 2 (.01)	-22.7 (.01)	342	-17 0	-19.9
38 0	344	-11 3 (.01)	-15.4 (.01)	377	-10.1	-16 3
42 0	364	-3 0 (01)	-14.0 (.01)	401	-4.2	-12 7
	Average	-12.7	-19 4		-12.8	-18 8

[a]U.S. linerboard results used as reference

It may be noted that all the differences are statistically significant at the 1% confidence level The Enso Gutseit linerboards average 12 to 13% lower and the Svenska Cellulosa 18 to 20% lower The biggest differences are in the 25.6, 26 0-lb. and 30 7, 33.0-lb. grade weight levels. When the results are compared on an equal weight basis, the differences diminish considerably, however, the U S linerboards still exhibit higher cross-machine tearing strength as may be seen from the differences tabulated. It is questionable, however, whether the difference between U.S and Enso Gutseit linerboards at the 41 0, 42 0-lb. grade weight level is significant.

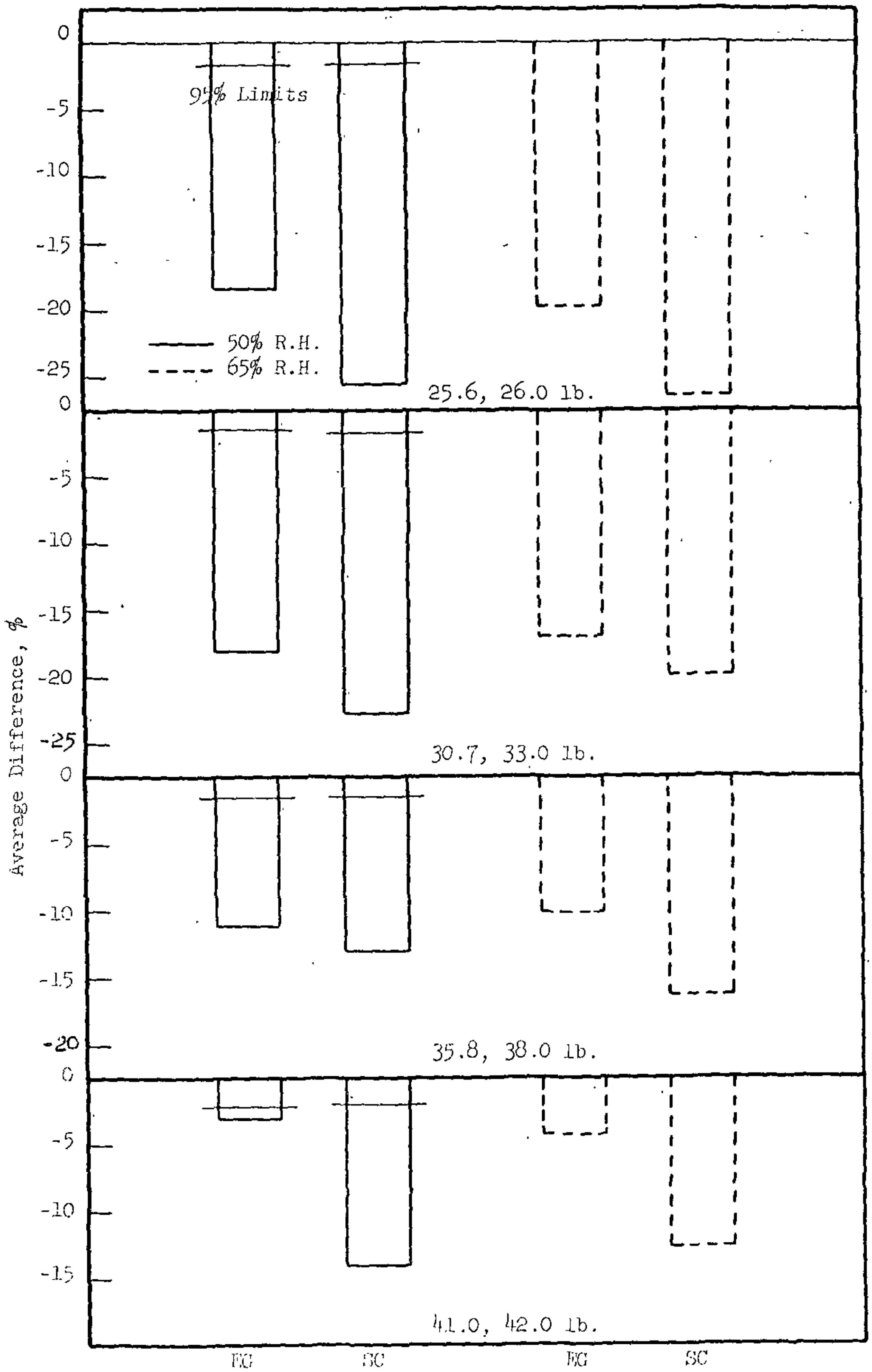


Figure [illegible]. Comparison of Average Difference in Cross-Direction [illegible] and U. S. Liner [illegible]

Difference in Cross-Machine Tearing Strength, %[a]

Nominal Wt., lb / M sq.ft	50% R.H. U.S. Linerboard C.D. Tearing Strength Factor	50% R.H. E.G.	50% R.H. S.C.	65% R.H. U.S. Linerboard C.D. Tearing Strength Factor	65% R.H. E.G.	65% R.H. S.C.
26.0	8.93	-13.8	-21.9	10.07	-17.4	-23.1
33.0	8.08	-10.0	-12.7	9.58	-8.5	-9.2
38.0	8.73	-6.5	-8.5	9.68	-5.7	-10.7
42.0	8.50	-0.1	-7.1	9.18	-1.3	-4.7
	Average	-7.6	-12.6		-8.2	-11.2

[a]U.S. linerboard results used as reference

In view of the behavior of the three types of linerboard relative to Elmendorf tearing strength, it would be expected that U.S. linerboards would also give higher torsion tear performance. This is the case as may be seen from the differences tabulated (see Tables XXXIII and XXXIV) and illustrated graphically in Fig. 21 and 22.

Difference in Torsion Tear Strength, %[a]

Nominal Wt., lb / M sq.ft.	In-Machine U.S. Linerboard Torsion Tear, unit	In-Machine E.G.	In-Machine S.C.	Cross-Machine U.S. Linerboard Torsion Tear, unit	Cross-Machine E.G.	Cross-Machine S.C.
		50% R.H.				
26.0	50	-12.0	-10.0	56	-14.3	-7.1
33.0	60	-16.7	-8.3	74	-25.7	-29.7
38.0	71	-29.6	-9.9	83	-28.9	-21.7
42.0	70	-15.7	-11.4	86	-16.3	-22.1
	Average	-18.5	-9.9		-21.3	-20.2

[a]U.S. linerboard results used as reference

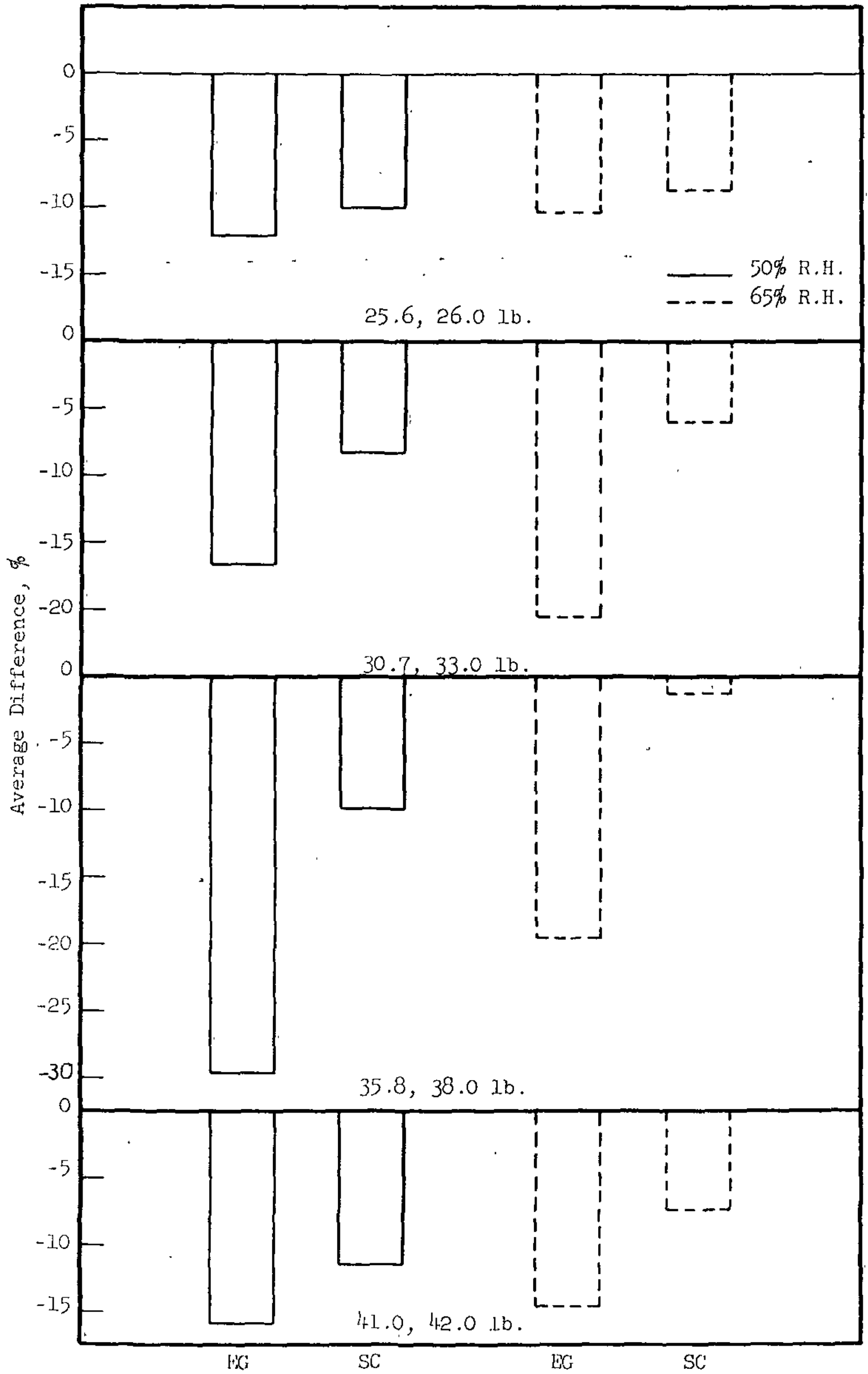


Figure 21. Comparison of Average Difference in Machine-Direction Torsion Tear of European and U.S. Linerboards

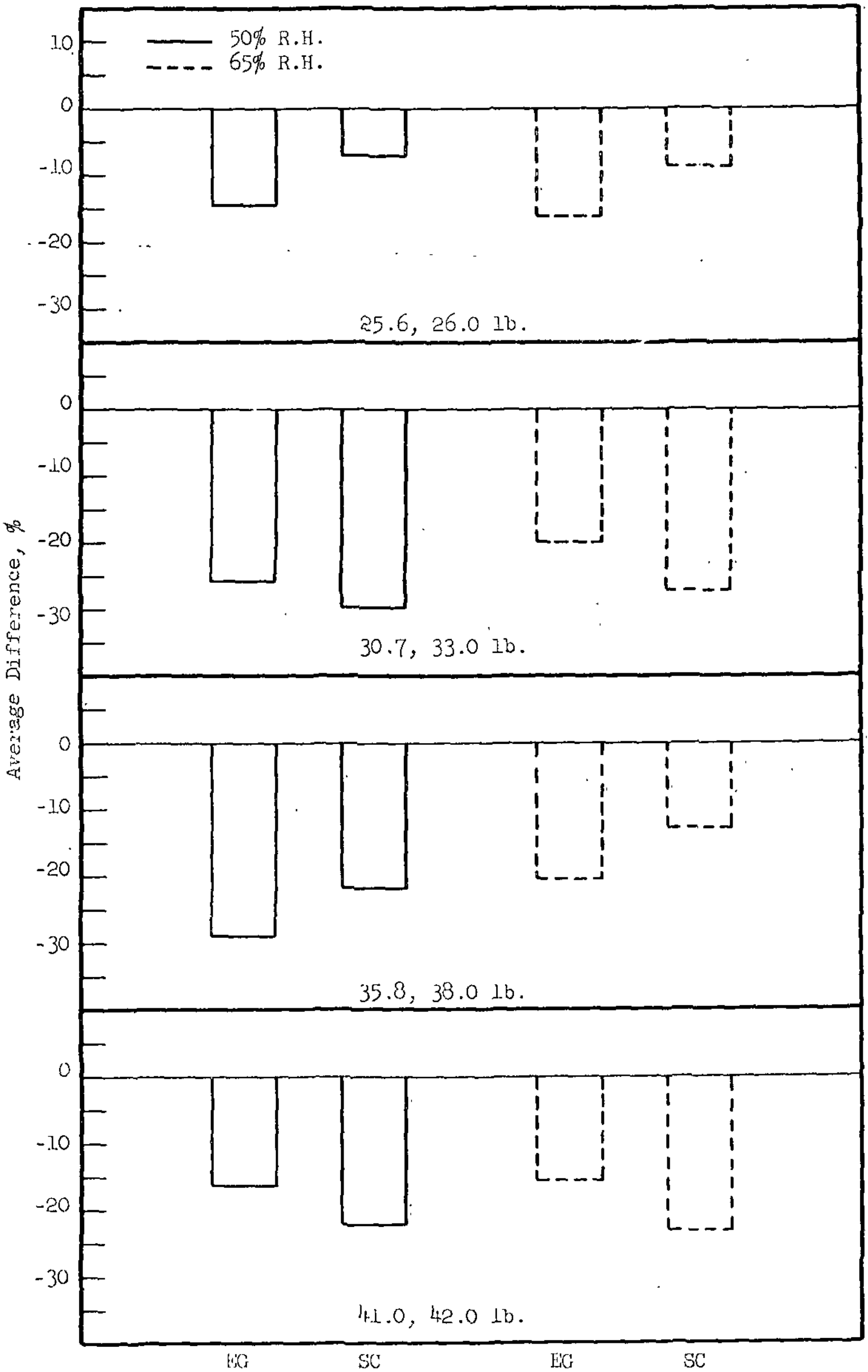


Figure 22. Comparison of Average Difference in Cross-Direction Torsion Tear of European and U.S. Linerboards

	Difference in Torsion Tear Strength, %[a]					
	In-Machine			Cross-Machine		
Nominal Wt., lb / M sq.ft	U.S Linerboard Torsion Tear, unit	E G	S.C.	U.S. Linerboard Torsion Tear, unit	E.G	S.C.
		65% R.H.				
26.0	58	-10.3	-8 6	68	-16.2	-8.8
33 0	68	-20 6	-5.9	85	-20.0	-27.1
38.0	77	-19.5	-1.3	94	-20.2	-12.8
42.0	83	-14.6	-7 3	104	-15.4	-23 1
	Average	-16 3	-5 7		-18.0	-18.0

[a] U.S. linerboard results used as reference.

On an average basis, U.S. linerboards are 16 to 18% higher in machine-direction torsion tear than the corresponding Enso Gutseit linerboards In contrast, U.S. linerboards are only 5 to 10% higher than Svenska Cellulosa liner-boards When cross-machine strengths are considered, it may be seen that U S. linerboards are 18 to 21% higher than the European linerboards Converting the results to a unit weight basis reduces the differences; in most instances, U.S. linerboards are still higher However, some of the differences between U.S. and Svenska Cellulosa linerboards on a unit weight basis may not be significant.

The puncture strength of the linerboards (see Tables XXXIII and XXXIV) exhibit a trend similar to those just described for Elmendorf tearing strength and torsion tear strength in that the U.S. linerboards generally give higher test values As may be seen in the following tabulation of per cent difference and in Fig. 23 and 24 the superiority of U S. linerboards is greatest at the two lower grade weight levels.

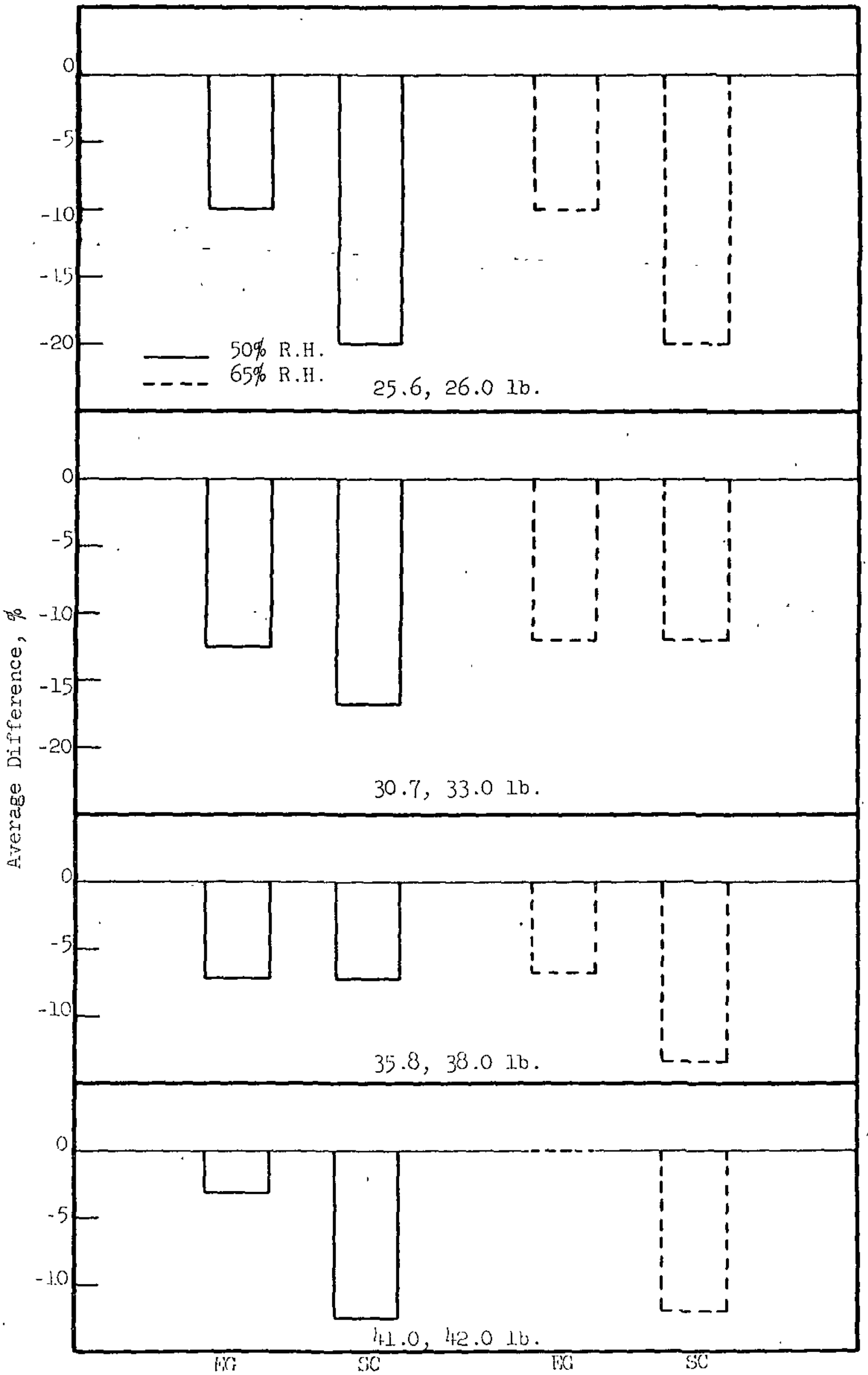


Figure 23. Comparison of Average Difference in Machine-Direction Fracture of European and U.S. Linerboards

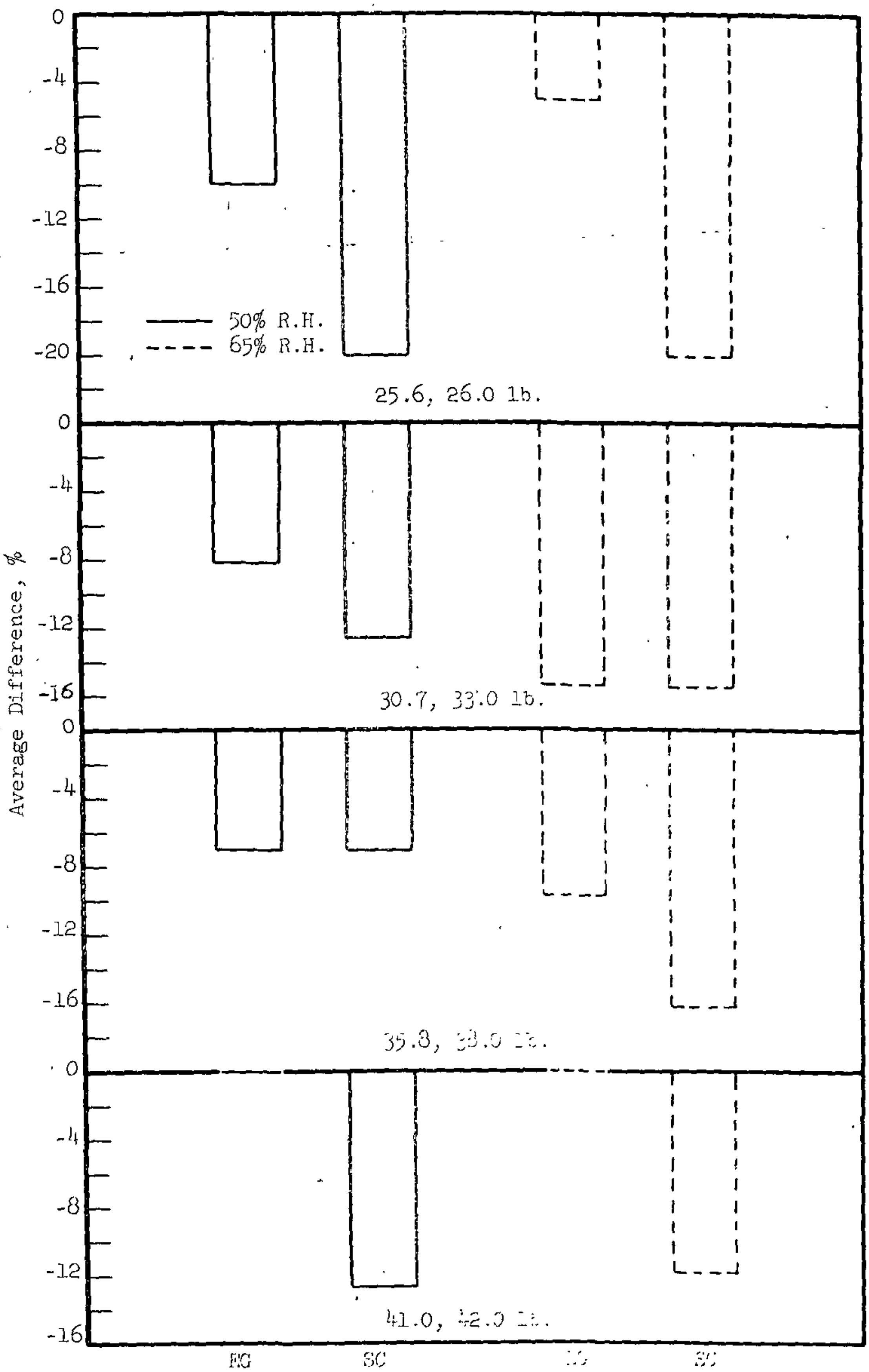


Figure 24. Comparison of Average Difference in Cross-Direction Puncture of European and U.S. Linerboard

Nominal Wt., lb / M sq.ft	Difference in Puncture Strength, %[a]					
	In-Machine			Cross-Machine		
	U.S. Linerboard Puncture, unit	E G	S C	U.S. Linerboard Puncture, unit	E G	S.C.
			50% R.H.			
26 0	20	-10.0	-20 0	20	-10 0	-20.0
33 0	24	-12.5	-16.7	24	-8.3	-12 5
38.0	28	-7 1	-7 1	28	-7 1	-7 1
42 0	32	-3.1	-12 5	32	0 0	-12 5
	Average	-8 2	-14 1		-8 2	-14.1
			65% R.H.			
26.0	20	-10 0	-20 0	20	-5 0	-20.0
33 0	25	-12.0	-12 0	26	-15 4	-15.4
38 0	30	-6.7	-13 3	31	-9 7	-16.1
42 0	34	0 0	-11 8	34	0 0	-11.8
	Average	-7 2	-14 3		-7 5	-15 8

[a]U S. linerboard results used as reference

Because of the lower basis weight associated with the European linerboards, converting the puncture results to a unit weight basis has the effect of decreasing the differences noted above. In most instances the U S. linerboards exhibit higher puncture on an equal weight basis than European linerboards

The modified ring compression test is a measure of the edgewise compression strength of the components and is considered to be an important cross-machine direction property of linerboard and corrugating medium from the standpoint of top-load compression. It was shown earlier that the cross-machine edgewise compression strength of the corrugated board is the most important combined board property in so far as top-load box compression is concerned. It has been found that, as a first approximation, the edgewise compression strength of corrugated board in the cross-machine direction is equal to the sum of the cross-machine direction edgewise compression (modified ring compression) strength of the components --i.e., the sum of this test property for the single-face linerboard, double-face linerboard, and corrugating medium corrected for draw. In so far as end-load compression is concerned, machine-direction edgewise compression strength of corrugated board is the most important combined board property. However, machine-direction combined board edgewise compression strength is not equal to the sum of the machine-direction modified ring compression results for the components because failure in combined board stressed in the machine direction manifests itself as interflute buckling instead of compression of the linerboard, especially of the single-face linerboard; consequently, flexural stiffness of the linerboard in the machine direction and not its edgewise compression strength is of greater import in consideration of end-load box compression and is related to machine-direction edgewise compression of combined board as indicated below:

$$P_{mx} = k(D_x/W^2)^{0.5} \qquad (3)$$

where

P_{mx} = machine-direction edgewise compression of combined board, lb./in.

k = constant

D_x = flexural stiffness of linerboard in machine direction, lb.-in.

W = distance between flute tips, in.

The differences in machine-direction modified ring compression tabulated in Tables XXXIII and XXXIV are listed as follows and graphed in Fig. 25:

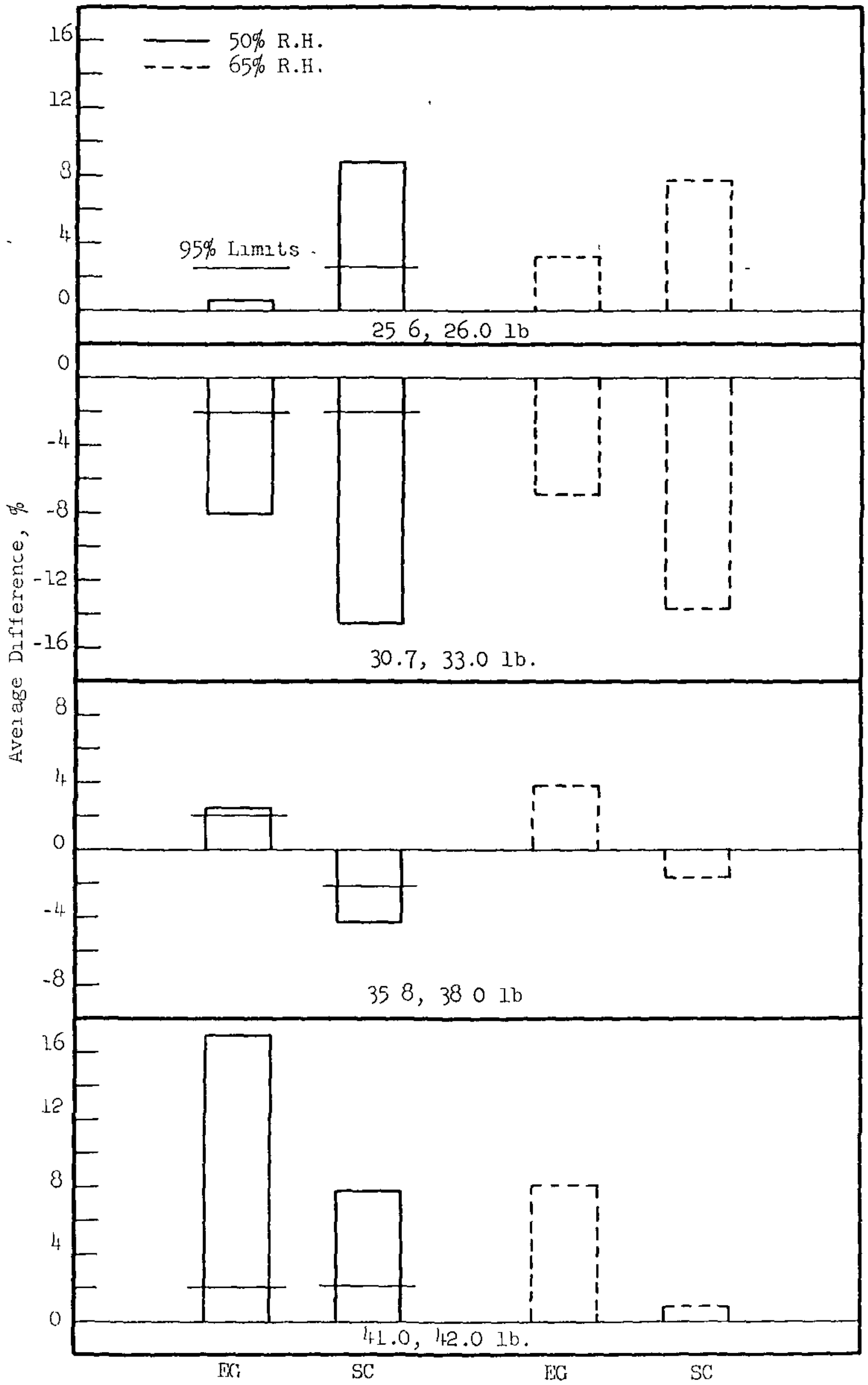


Figure 25. Comparison of Average Difference in Machine-Direction Modified Ring Compression of European and U.S. Linerboard

Difference in Machine-Direction Modified Ring Compression Strength, %[a]

Nominal Wt., lb. M sq. ft.	50% R.H. U.S. Linerboard M.D. Modified Ring Compression, lb./in.	50% R.H. E.G.	50% R.H. S.C.	65% R.H. U.S. Linerboard M.D. Modified Ring Compression, lb./in.	65% R.H. E.G.	65% R.H. S.C.
[illegible]	16.0	+0.6 (NS)	+8.8 (.05)	15.4	+3.2	+7.8
[illegible]	23.[illegible]	-8.1 (.01)	-14.5 (.01)	23.2	-6.9	-13.8
[illegible]	24.0	+2.5 (.01)	-4.2 (.01)	23.7	+3.8	-1.7
42.0	19.3	+17.1 (.01)	+7.8 (.01)	20.8	+8.2	+1.0
	Average	+3.0	-0.5		+2.1	-1.7

[a] U.S. [illegible] results used as reference.

[illegible] may be noted that at the 25.6, 26.0-lb. grade weight level the [illegible] exhibits lower machine-direction modified ring compression [illegible] the European linerboards; however, the difference between U.S. [illegible] linerboard is not significant and the corresponding difference [illegible] U.S. [illegible] Svenska Cellulosa linerboard is significant only at the 5% level [illegible]. At the 30.7, 33.0-lb. grade weight level, the U.S. linerboards [illegible] higher results than the European linerboards. At the 35.8, [illegible] weight level the results for Enso Gutseit linerboard are signifi[illegible] than the results for U.S. linerboard, and the results for Svenska [illegible] significantly lower. At the 41.0, 42.0-lb. grade weight [illegible] board used in this study is associated with modified ring [illegible] significantly lower than the results for the corresponding [illegible], the greater disparity being with the Enso Gutseit liner-

The average differences in cross-machine modified ring compression strength are shown in the following tabulation (see Table XXXIII and XXXIV) and illustrated in Fig 26

	Difference in Cross-Machine Modified Ring Compression, %[a]					
	50% R H			65% R.H.		
Nominal Wt., lb./M sq.ft	U S. Linerboard C D Modified Ring Compression, lb /in	E.G.	S C	U.S Linerboard C D Modified Ring Compression, lb /in	E G	S C.
26.0	11.7	-0.9 (NS)	+2.6 (NS)	10 8	-1 9	+0 9
33.0	16 0	-5 0 (.05)	-11 2 (01)	14.9	-4 7	-6 0
38.0	15 6	+14 1 (.01)	+5 8 (01)	14 6	+13 7	+9 6
42 0	15 4	+7 8 (.01)	+3 9 (05)	15 8	+11 4	+2.5
	Average	+4.0	+0 3		+4 6	+4.5

[a]U S. linerboard results used as reference.

It may be noted that, as in the case of machine-direction modified ring compression strength at the 25 6, 26 0-lb. grade weight level, there is no highly significant difference in cross-machine modified ring compression strength between U.S and European linerboards At the 30.7, 33 0-lb grade weight level, U.S. linerboard gives slightly higher results than European linerboards At the 35 8, 38.0-lb. and 41 0, 42.0-lb grade weight levels the U S linerboards are lower in cross-machine modified ring compression strength than the European linerboards

Taber stiffness, a measure of flexural stiffness, is of secondary importance in top-load compression but of primary importance in end-load box compression As previously described, the machine-direction edgewise compression strength of corrugated combined board, which is the most important combined board property

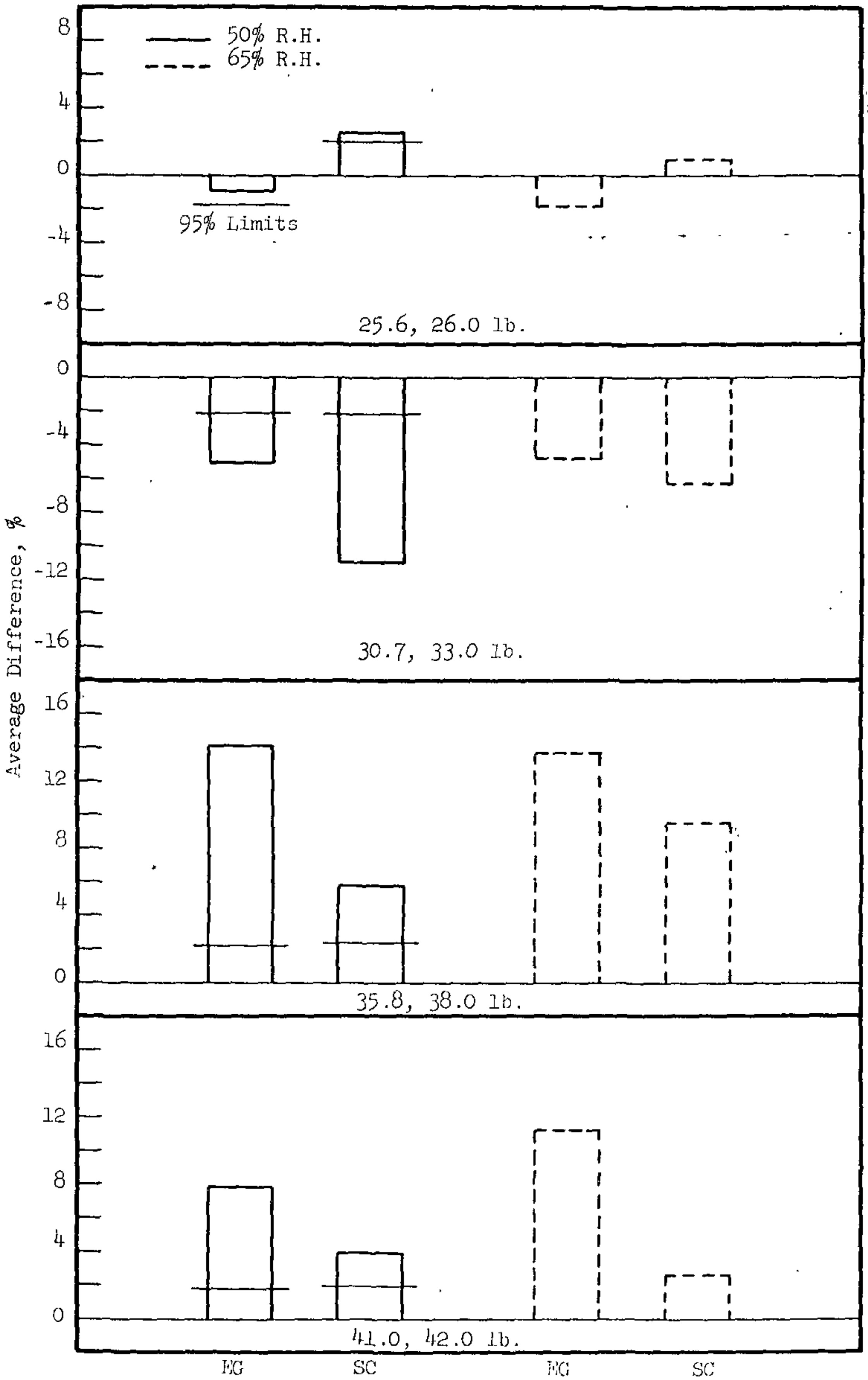


Figure 26. Comparison of Average Difference in Cross-Direction
Modified [illegible]

in so far as end-load box compression is concerned, is governed by the machine-direction flexural stiffness of the linerboard and the distance between flute tips Flexural stiffness, both in and cross, enter into top-load compression through their secondary influence on the cross-machine edgewise compression strength of combined board

- - - - - -

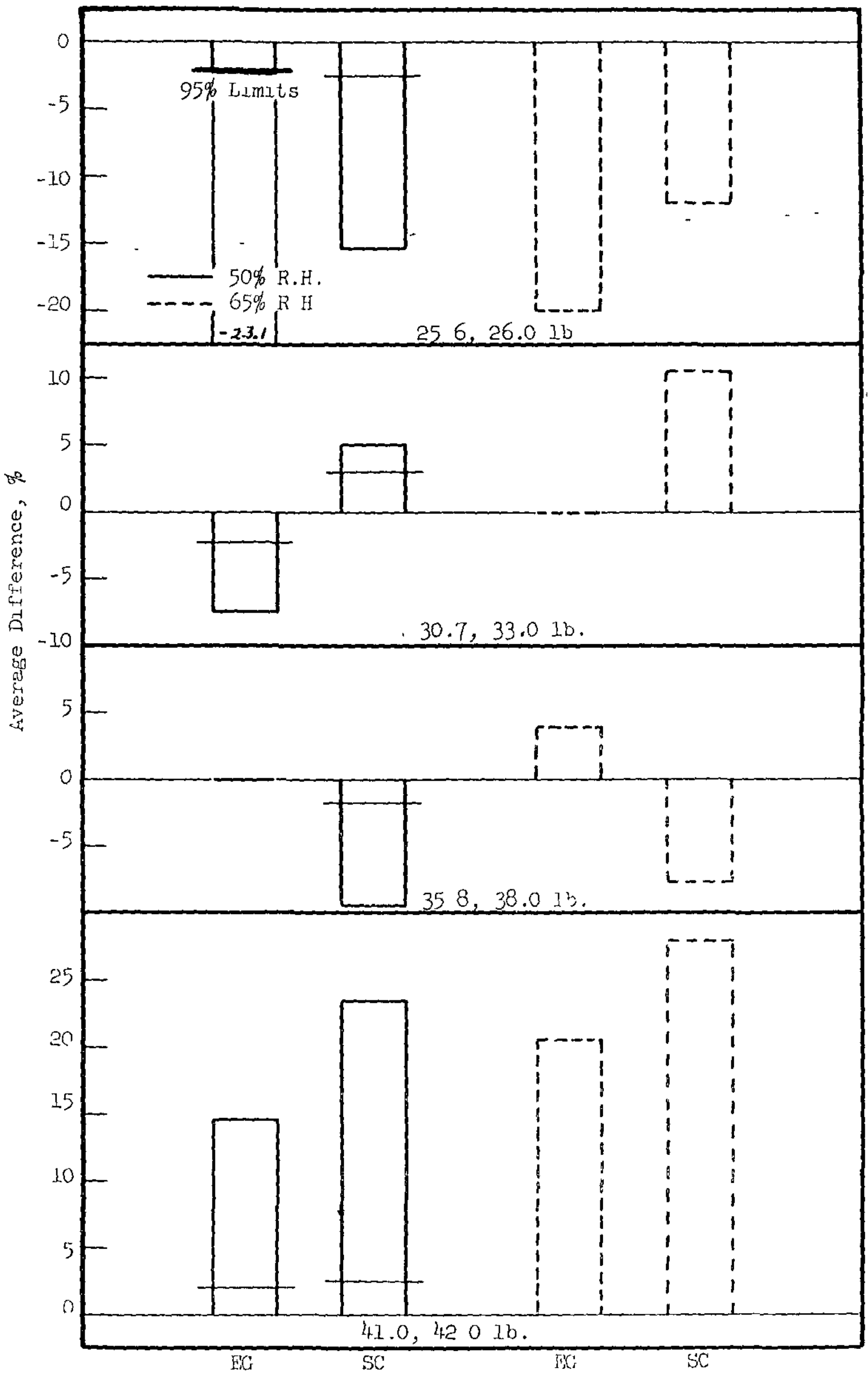
The machine-direction Taber stiffnesses are tabulated in Tables XXXIII and XXXIV. For the purpose of comparison the average differences in Taber stiffness results between U.S and European linerboards are listed as follows and graphically presented in Fig 27

Average Differences in Machine-Direction Taber Stiffness, %[a]

	50% R.H.			65% R H.		
Nominal Wt., lb./M sq.ft	U.S. Linerboard M.D. Taber Stiffness, g.cm.	E G	S.C.	U S Linerboard M D. Taber Stiffness, g.cm	E G	S.C.
26.0	26	-23.1 (01)	-15 4 (01)	25	-20 0	-12 0
33 0	40	-7 5 (NS)	+5 0 (NS)	38	0.0	+10 5
38.0	53	0.0 (-)	-9 4 (.01)	52	+3 8	-7 7
42.0	63	+14.7 (.01)	+23 5 (.01)	68	+20 6	+27 9
	Average	-4.0	+0.9		+1 1	+4 7

[a]U S. linerboard results used as reference

It may be seen that at the 25 6, 26 0-lb. grade weight level, the U S linerboard gives significantly higher flexural stiffness (Taber) than the competitive grade weights of European linerboards At the 30 7, 33 0-lb grade weight level there is no significant difference between U S and European linerboards. At the 35 8, 38.0-lb grade weight level there is no significant difference between U.S and Enso Gutzeit linerboards, however, the Svenska Cellulosa



igure 27 Comparison of Average Difference in Machine-Direction

linerboards are significantly lower At the 41 0, 42 0-lb grade weight level the U.S. linerboard gives significantly lower (15 to 30%) Taber stiffness than the European linerboards

The average differences in cross-machine Taber stiffness are tabulated as follows (see Tables XXXIII and XXXIV) and illustrated in Fig 28

	Average Difference in Cross-Machine Taber Stiffness, %[a]					
	50% R.H.			65% R.H.		
Nominal Wt., lb./M sq.ft.	U S Linerboard C.D. Taber Stiffness, g.cm.	E G	S C	U.S. Linerboard C.D Taber Stiffness, g cm	E.G.	S.C.
26.0	10	-20 0 (.05)	-20 0 (NS)	10	-40 0	-30 0
33.0	14	-7 1 (.05)	0 0 (NS)	14	-14.3	0 0
38 0	16	+31.2 (.01)	+12.5 (.01)	16	+25 0	+6.2
42 0	23	+30.4 (.01)	+17.4 (.01)	24	+25.0	+4 2
	Average	+8 6	+2.5		-1 1	-4.9

[a]U.S. linerboard results used as reference.

It may be observed that at the 25.6, 26 0-lb grade weight level the U S. linerboard gives higher cross-machine Taber stiffness results than the European linerboards. There appears to be no difference between U.S. and Svenska Cellulosa linerboards at the 30 7, 33 0-lb grade weight level, however, the U.S linerboard gives higher results than Enso Gutseit linerboard At the 35.8, 38.0-lb. and 41 0, 42.0-lb grade weights the U.S. linerboards are lower than the corresponding European linerboards

The difference in tensile properties between U.S. and European linerboards may be seen from the results tabulated in Tables XXXIII and XXXIV For

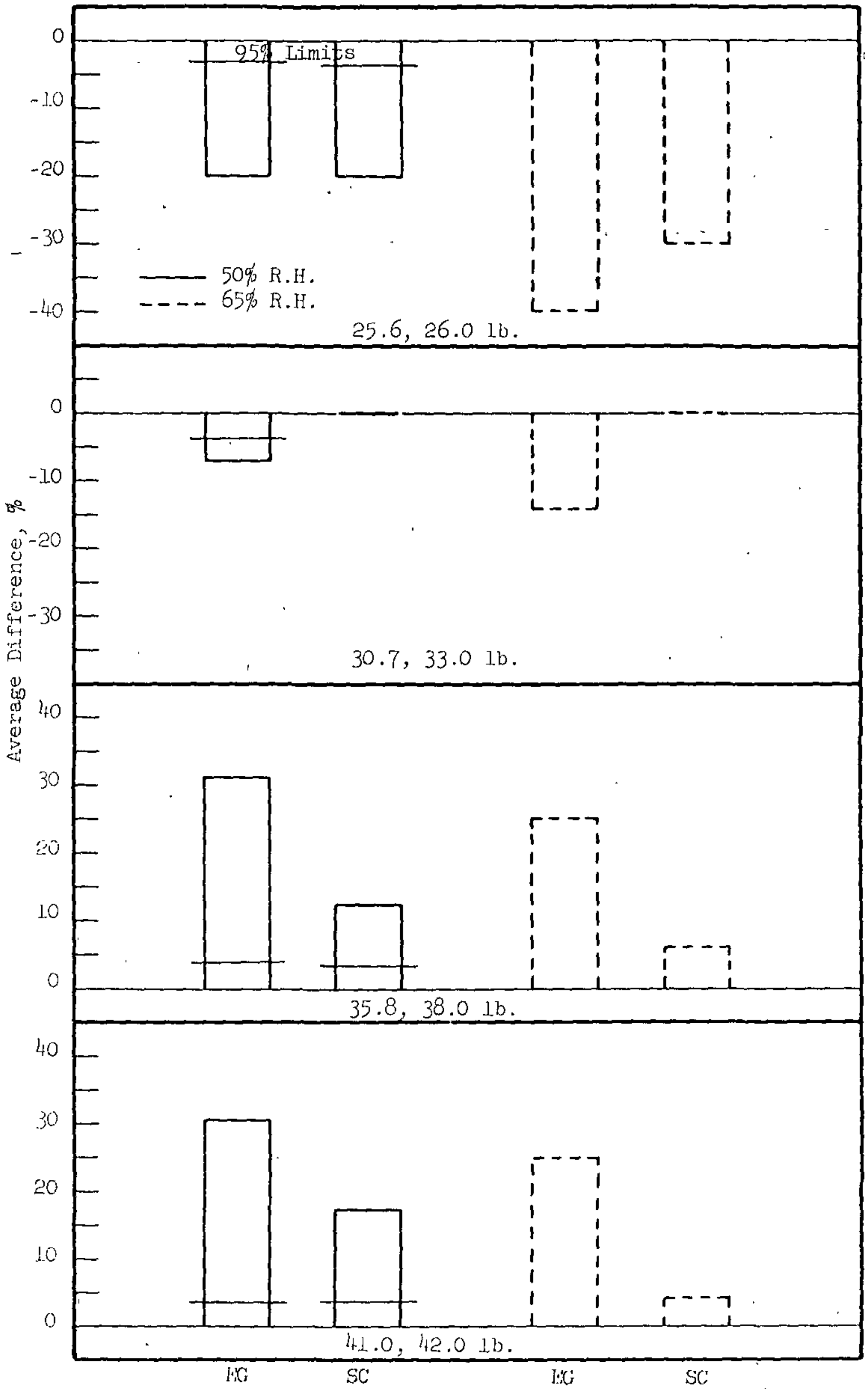


Figure 28. Comparison of Average Difference in Cross-Direction
[illegible]

the purpose of comparison the average differences in machine-direction tensile strength are given as follows and are graphically illustrated in Fig. 29:

	Average Difference in Machine-Direction Tensile Strength, %[a]					
	50% R.H.			65% R.H.		
Nominal Wt., lb./ M sq.ft.	U.S. Linerboard M.D. Tensile Strength, lb./in.	E.G.	S.C.	U.S. Linerboard M.D. Tensile Strength, lb./in.	E.G.	S.C.
26.0	57.0	+39.6	+57.5	52.8	+42.8	+66.3
33.0	86.6	+23.6	+13.2	81.5	+22.0	+11.7
38.0	86.0	+35.8	+29.1	80.4	+35.2	+28.1
42.0	95.2	+31.7	+32.8	89.5	+29.2	+30.9
	Average	+32.8	+33.5		+32.3	+34.3

[a] U.S. linerboard results used as reference.

It may be seen that the U.S. linerboards are significantly lower in machine-direction tensile strength than the European linerboards. The differences range from 12 to 66%. The biggest difference is at the 25.6, 26.0-lb. grade weight level and the smallest difference is at the 30.7, 33.0-lb. grade weight level. When the machine direction tensile strength results are calculated on a unit weight basis, the differences between U.S. and European linerboards increase, as would be expected, because of the lower weight of the European linerboards.

The cross-machine tensile strength results are shown in the following table in terms of average differences and are illustrated in Fig. 30:

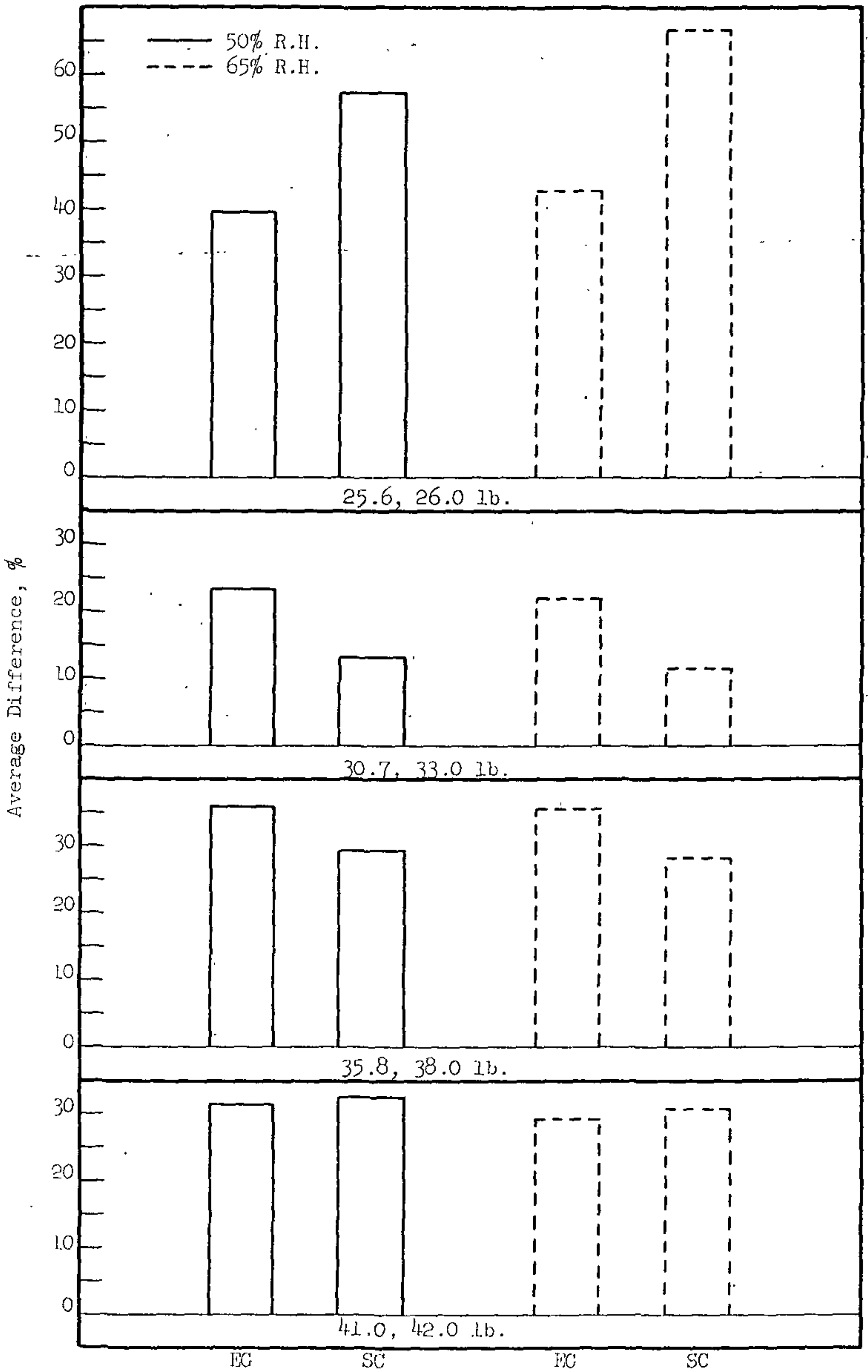


Figure 29. Comparison of Average Difference in Machine-Direction Tensile Strength of European and U.S. Linerboards

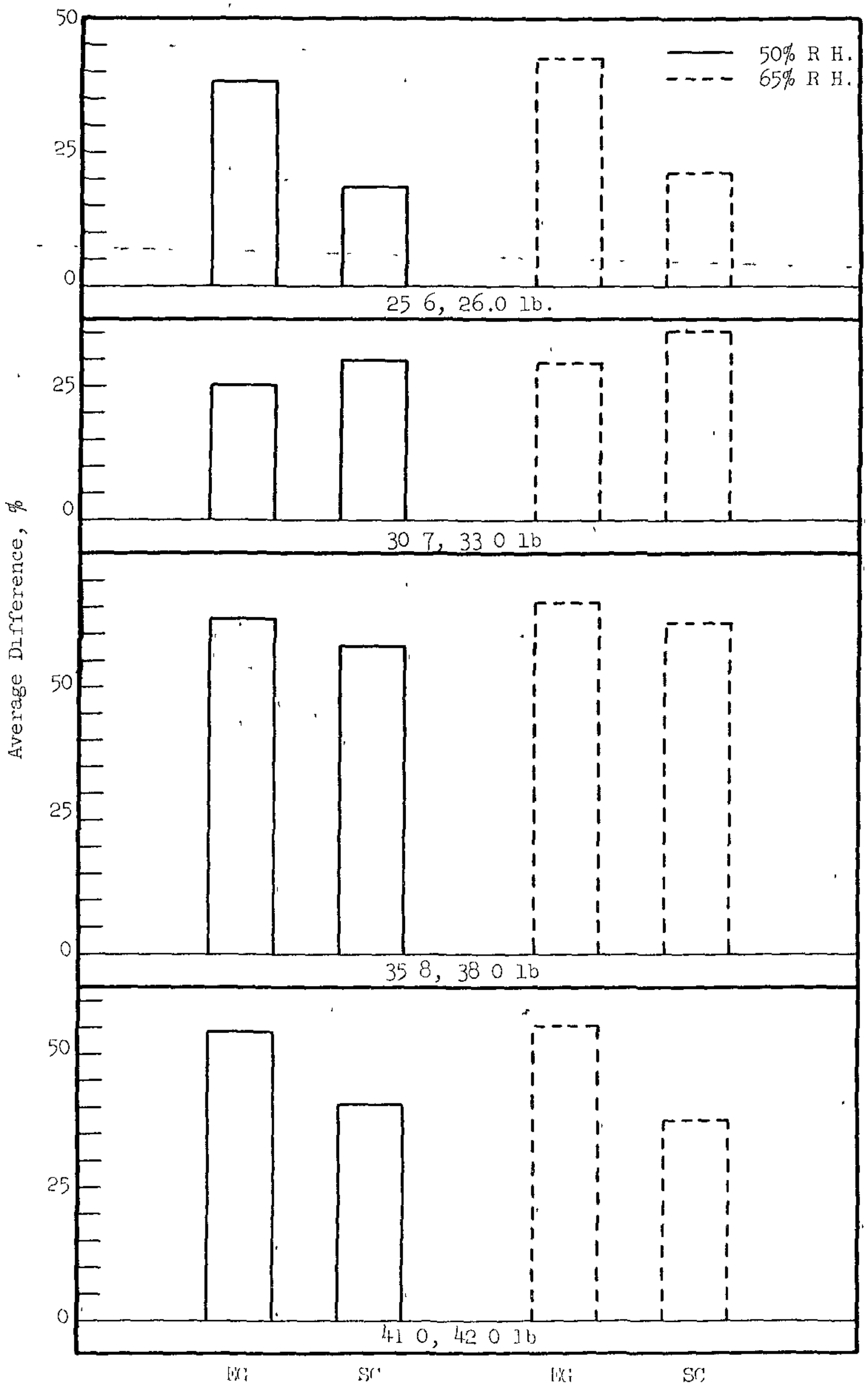


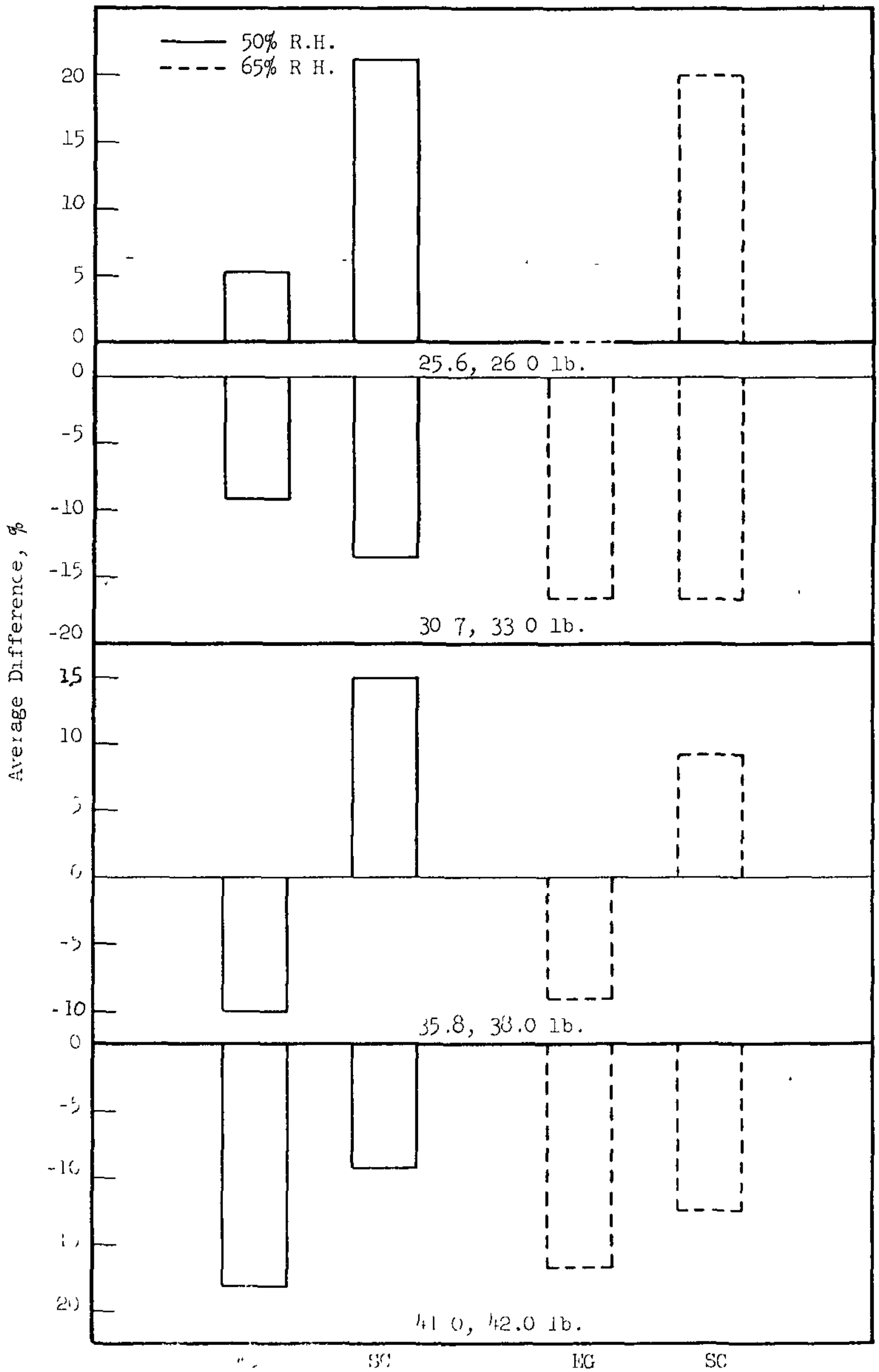
Figure 30 Comparison of Average Difference in Cross-Direction Tensile Strength of European and U S Linerboards

Nominal Wt., lb./M sq.ft.	Average Difference in Cross-Machine Tensile Strength, %[a]					
	50% R.H.			65% R.H.		
	U.S. Linerboard C.D. Tensile Strength, lb./in.	E.G.	S.C.	U.S. Linerboard C.D. Tensile Strength, lb./in.	E.G.	S.C.
26.0	57.0	+37.8	+18.9	52.8	+43.3	+21.6
33.0	86.6	+25.2	+29.8	81.5	+28.7	+33.3
38.0	86.0	+63.3	+58.5	80.4	+65.9	+62.2
42.0	95.2	+54.1	+41.0	89.5	+55.1	+37.2
	Average	+45.1	+37.0		+48.2	+38.6

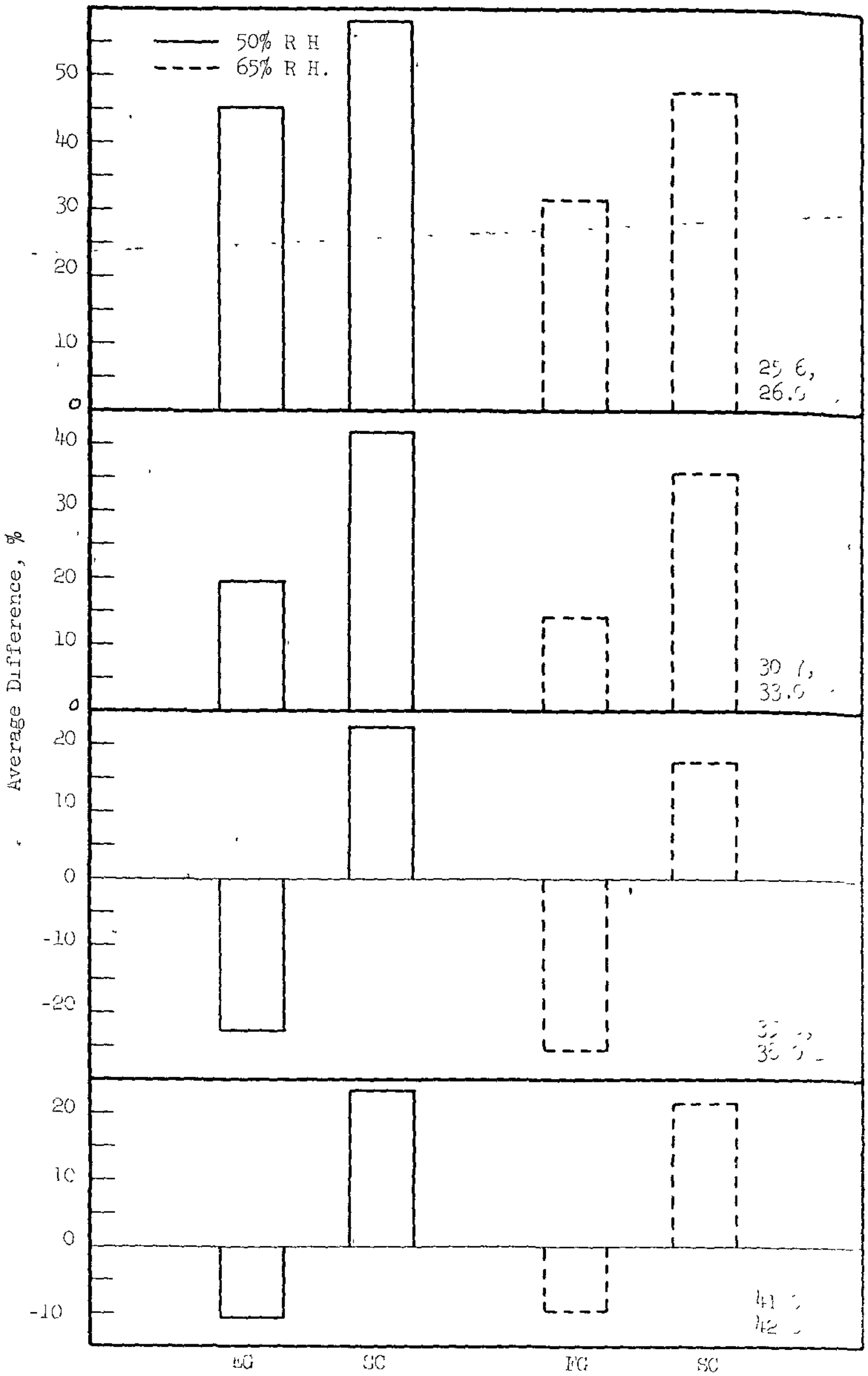
[a] U.S. linerboard results used as reference.

As in the case of the machine-direction tensile strength, the U.S. linerboards are significantly lower in cross-machine tensile strength when compared with the European linerboards. It is believed that the greater cross-machine tensile strength is responsible for the relatively good rough handling performance of the boxes made with European linerboards even though their tearing strengths are lower than those of the corresponding U.S. linerboards. When the cross-machine tensile strengths are calculated on a unit weight basis, the differences are increased in favor of the European linerboards.

The stretch characteristics of the linerboard play an important role (a) in rough handling performance, particularly cross-machine stretch and tensile, (b) in folding at the scorelines, and (c) in flexural stiffness. For the purpose of comparison, the average differences in stretch characteristics are shown in the following table (see Tables XXXIII and XXXIV) and are graphically illustrated in Fig. 31 and 32:



[illegible] Average Difference in Machine-Direction
[illegible] European and U S. Linerboards



Average Difference in Cross

Nominal Wt., lb./M sq.ft.	Average Difference in Stretch Characteristics, %[a]					
	In-Machine			Cross-Machine		
	U.S. Linerboard Stretch, %	E.G.	S.C.	U.S. Linerboard Stretch, %	E.G.	S.C.
			50% R.H.			
26.0	1.8	+5.6	+22.2	3.1	+45.2	+58.1
33.0	2.2	-9.1	-13.6	3.6	+19.4	+41.7
38.0	2.0	-10.0	+15.0	4.4	-22.7	+22.7
42.0	2.2	-18.2	-9.1	3.8	-10.5	+23.7
	Average	-7.9	+3.6		+7.9	+36.6
			65% R.H.			
26.0	2.0	0.0	+20.0	3.8	+31.6	+47.4
33.0	2.4	-16.7	-16.7	4.2	+14.3	+35.7
38.0	2.2	-9.1	+9.1	5.1	-25.5	+17.6
42.0	2.4	-16.7	-12.5	4.2	-9.5	+21.4
	Average	-10.6	0.0		+2.7	+30.5

[a]U.S. linerboard results used as reference.

It may be observed that the U.S. linerboards have higher machine-direction stretch than the corresponding linerboards made by Enso Gutseit except possibly at the 25.6, 26.0-lb. grade weight level at which they are approximately equal. In contrast, the Svenska Cellulosa linerboards have higher stretch at the 25.6, 26.0-lb. and 35.7, 38.0-lb. grade weight levels but lower stretch characteristics at the 30.7, 33.0-lb. and 41.0, 42.0-lb. grade weight levels.

When cross-machine stretch is considered, it may be noted that the U.S. linerboards have higher stretch than the Enso Gutseit linerboards at the 35.7, 38.0-lb. and 41.0, 42.0-lb. grade weight levels, but lower stretch at the two lowest grade weight levels. In contrast, the U.S. linerboards have lower cross-machine stretch at all four grade weight levels than the Svenska Cellulosa linerboards

The modulus of elasticity is defined as the ratio of stress to strain It is an important factor in flexural stiffness which is functionally related to <u>EI</u> where <u>E</u> is the modulus of elasticity and <u>I</u> is the moment of inertia. <u>E</u> is a material property dependent upon bonding, fiber length, etc , whereas <u>I</u> is a configurational property dependent on shape of cross section and dimensions Modulus of elasticity of linerboard plays an important role, because of its relationship to flexural stiffness of combined board and the machine-direction edgewise compression strength of combined board.

The moduli of elasticity are given in Tables XXXIII and XXXIV. For purposes of comparison the average differences in elastic moduli are given in the following tabulation and graphically illustrated in Fig. 33 and 34, respectively, for machine and cross-machine directions:

Average Differences in Elastic Moduli, %[a]

Nominal Wt., lb / M sq.ft	In-Machine: U.S Linerboard Modulus of Elasticity, lb /sq in. x 10^3	In-Machine: E.G.	In-Machine: S C	Cross-Machine: U S Linerboard Modulus of Elasticity, lb /sq.in x 10^3	Cross-Machine: E.G.	Cross-Machine: S.C.
50% R H.						
26 0	647	+52.9	+60.7	271	+35 1	+18.8
33.0	870	+33.8	+3.1	354	+20.9	-2.3
38.0	782	+42 5	+22 8	279	+68.5	+35.5
42 0	771	+57 5	+22 3	300	+51 3	+10 3

[a] U S. linerboard results used as reference

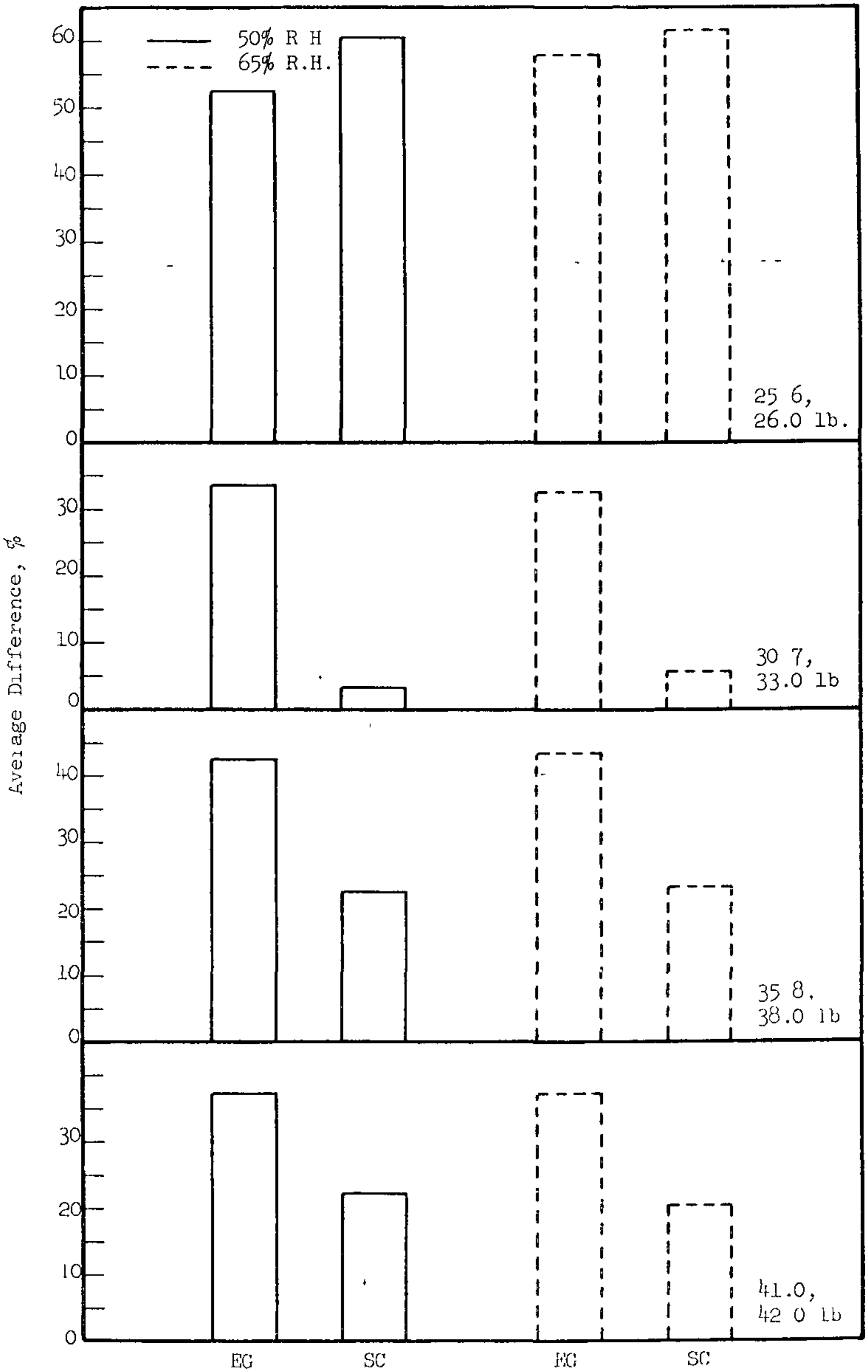


Figure 33 Comparison of Average Difference in Machine-Direction Modulus of Elasticity of European and U S Linerboards

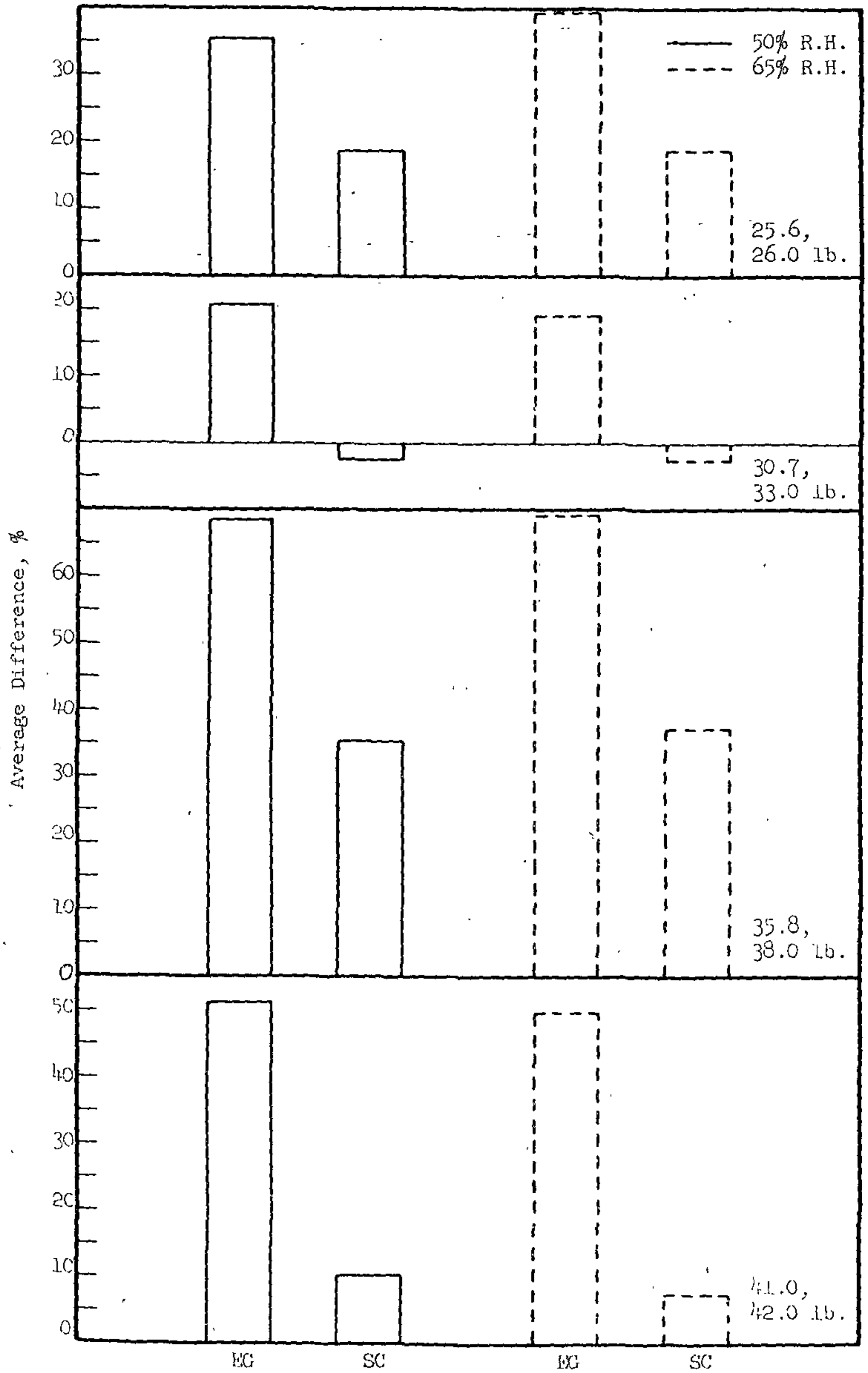


Figure 34. Comparison of Average Difference in Cross-Direction
[illegible]

Average Differences in Elastic Moduli, %[a]

Nominal Wt., lb./ M sq.ft.	In-Machine: U.S. Linerboard Modulus of Elasticity, lb./sq.in. x 10^3	In-Machine: E.G.	In-Machine: S.C.	Cross-Machine: U.S. Linerboard Modulus of Elasticity, lb./sq.in. x 10^3	Cross-Machine: E.G.	Cross-Machine: S.C.
			65% R.H.			
26.0	590	+58.0	+61.5	239	+39.3	+18.8
33.0	814	+32.7	+5.7	316	+19.0	-2.5
38.0	729	+43.2	+23.3	246	+69.1	+37.4
42.0	724	+37.2	+20.2	269	+49.8	+7.8

[a] U.S. linerboard results used as reference.

It may be seen that the U.S. linerboards are generally associated with lower moduli than the European linerboards. In most instances the differences are probably significant. The greatest difference is at the 25.6, 26.0-lb. grade weight level. Inasmuch as the modulus of elasticity is dependent to a large extent on the degree of bonding, as is bursting strength, the fact that U.S. linerboards give lower moduli should not be surprising.

The tensile energy absorption, T.E.A., is a measure of the energy absorption capacity of a linerboard. It is the energy corresponding to the area under the tensile load-deformation curve; thus, T.E.A. is a function of both tensile and the corresponding stretch characteristics. It may be recalled that the tensile strength of U.S. linerboards were lower than the corresponding European linerboards; however, the stretch characteristics varied from higher to lower depending on the grade weight and manufacturer; thus, it would be expected that the same may occur relative to T.E.A. For purposes of comparison, the average difference between U.S. and European linerboard in T.E.A. results are as follows (see Tables XXXIII and XXXIV) and graphically illustrated in Fig. 35 and 36, respectively, for machine- and cross-machine direction T.E.A.:

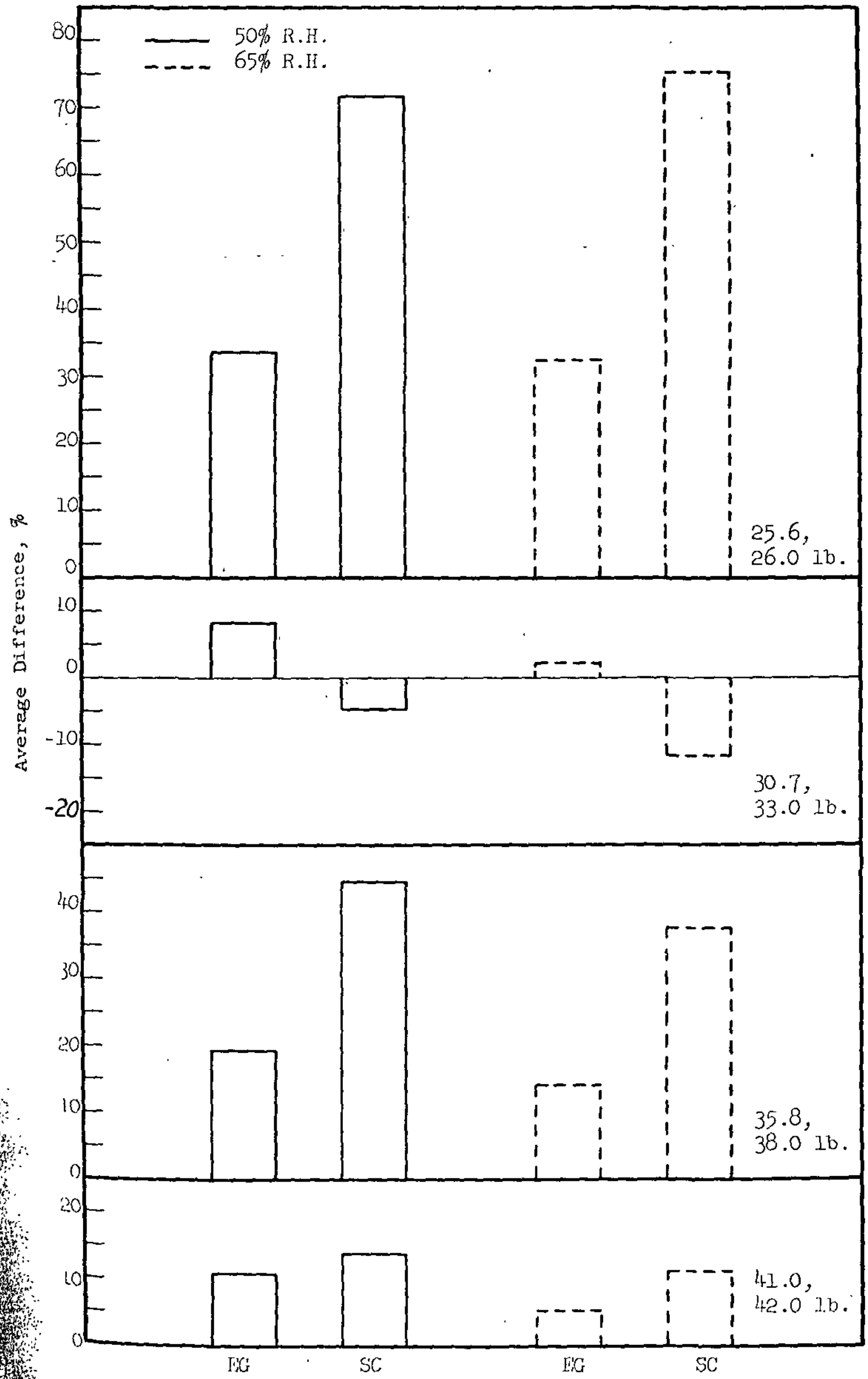


Figure 35. Comparison of Average Difference in Machine-Direction T.E.A. of European and U.S. Linerboards

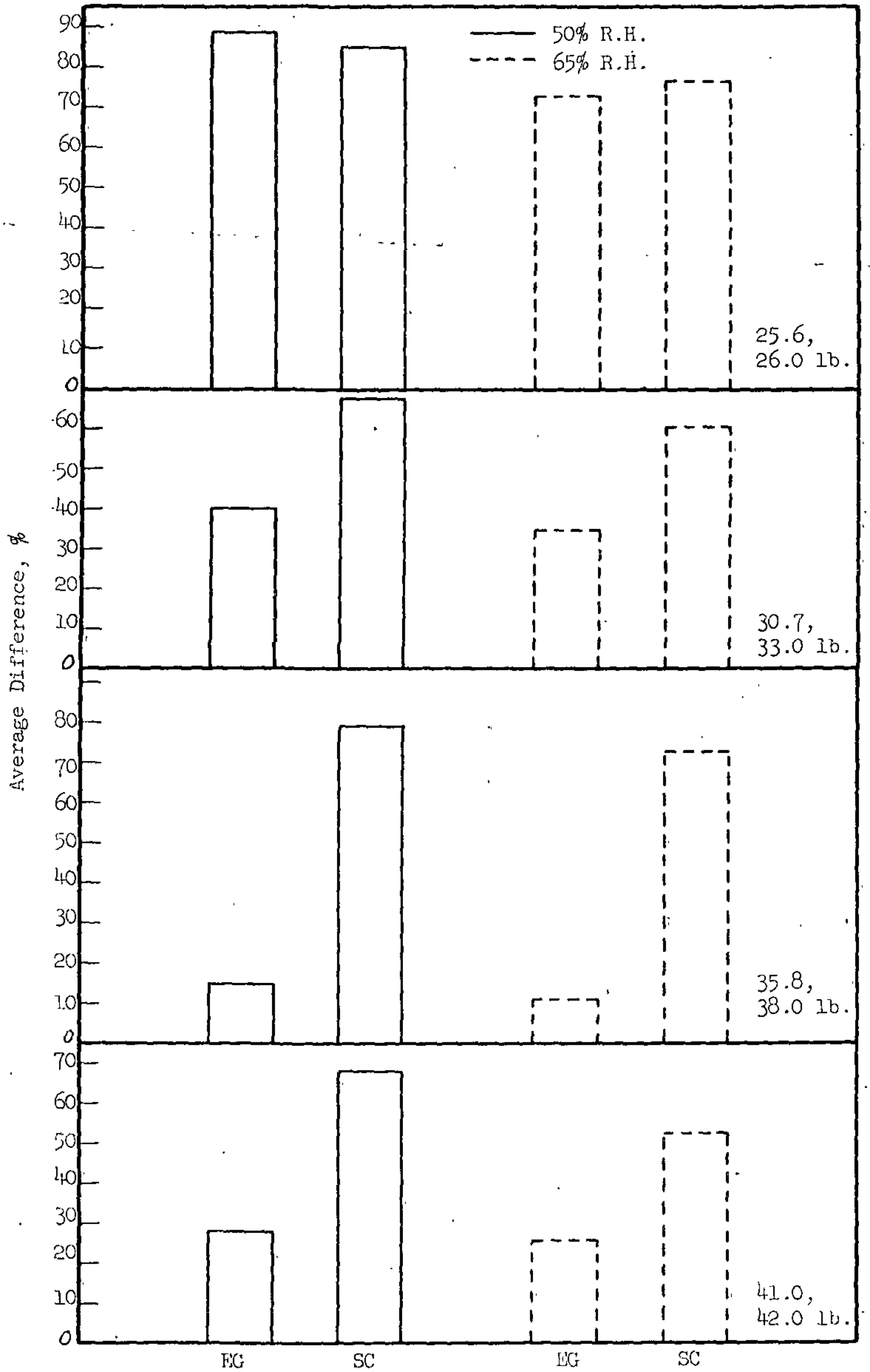


Figure 36. Comparison of Average Difference in Cross-Direction T.E.A. of European and U.S. Linerboards

Nominal Wt., lb./M sq.ft.	Average Difference in T.E.A. Results, %[a] — Machine Direction: U.S. Linerboard T.E.A., in.-lb./sq.in.	E.G.	S.C.	Cross-Machine Direction: U.S. Linerboard T.E.A., in.-lb./sq.in.	E.G.	[illegible]
		50% R.H.				
26.0	0.71	+33.8	+71.8	0.53	[illegible]	[illegible]
33.0	1.24	+8.1	-4.8	0.85	[illegible]	[illegible]
38.0	1.14	+19.3	+44.7	1.00	[illegible]	[illegible]
42.0	1.36	+11.0	+14.0	0.95	[illegible]	[illegible]
	Average	+18.0	+33.8		[illegible]	[illegible]
		65% R.H.				
26.0	0.74	+32.4	+75.7	0.60	+73.3	[illegible]
33.0	1.29	+2.3	-11.6	0.92	[illegible]	[illegible]
38.0	1.19	+14.3	+37.8	1.06	[illegible]	[illegible]
42.0	1.38	+5.8	+11.6	1.02	[illegible]	[illegible]
	Average	+13.7	+28.4		[illegible]	[illegible]

[a]U.S. linerboard results used as reference.

It may be seen that the T.E.A. characteristics of U.S. [illegible] lower than those for the corresponding grade weights of Enso Gutzeit [illegible]. The greatest difference is at the 25.6, 26.0-lb. grade weight level. [illegible] T.E.A. characteristics of U.S. linerboards are compared with those [illegible] Cellulosa linerboards, it may be noted that the T.E.A. values for U.S. [illegible] are lower except for the machine-direction value at the 30.7, 33.[illegible]-lb. [illegible] weight level. The greatest disparity is at the 25.6, 26.0-lb. grade [illegible]

The I.P.C. bond strength is a measure of the degree of [illegible] ing of the fibers, and, consequently, is related to the various [illegible] of the linerboard. The average differences in bond strength are as follows (see Tables XXXIII and XXXIV) and are graphically illustrated in Fig. 37 and 38, respectively, for machine and cross-machine bond strength:

	Average Difference in I.P.C. Bond Strength, %[a]					
	Machine Direction			Cross-Machine Direction		
Nominal Wt., lb./M sq.ft.	U.S. Linerboard Bond Strength, kp.cm./sec.	E.G.	S.C.	U.S. Linerboard Bond Strength, kp.cm./sec.	E.G.	S.C.
		50% R.H.				
26.0	4.34	-23.5	+13.1	3.13	-24.9	-19.8
33.0	4.55	-7.3	+51.6	2.26	+2.7	+39.8
38.0	3.24	+24.7	+70.1	1.68	+34.5	+57.1
42.0	4.76	-9.9	+23.1	2.27	+5.3	+13.7
	Average	-4.0	+39.5		+4.4	+22.7
		65% R.H.				
26.0	1.96	-9.2	+1.0	1.85	-9.7	+3.8
33.0	2.17	-1.8	+5.5	1.89	+12.2	+18.5
38.0	1.92	-1.0	+18.8	1.89	+1.6	+4.8
42.0	2.12	-4.7	+17.9	1.85	+8.6	+17.8
	Average	-4.2	+10.8		+3.2	+11.2

[a]U.S. linerboard results used as reference.

It may be noted that except in one instance the U.S. linerboards exhibit higher average machine-direction bond strength than the Enso Gutseit linerboards. In contrast, the Svenska Cellulosa linerboards gave higher machine-direction bond strength than the U.S. linerboards. When the cross-machine bond strengths are compared, it may be seen that at the 25.6, 26.0-lb. grade weight level, the U.S. linerboard gives higher results generally; at the three higher

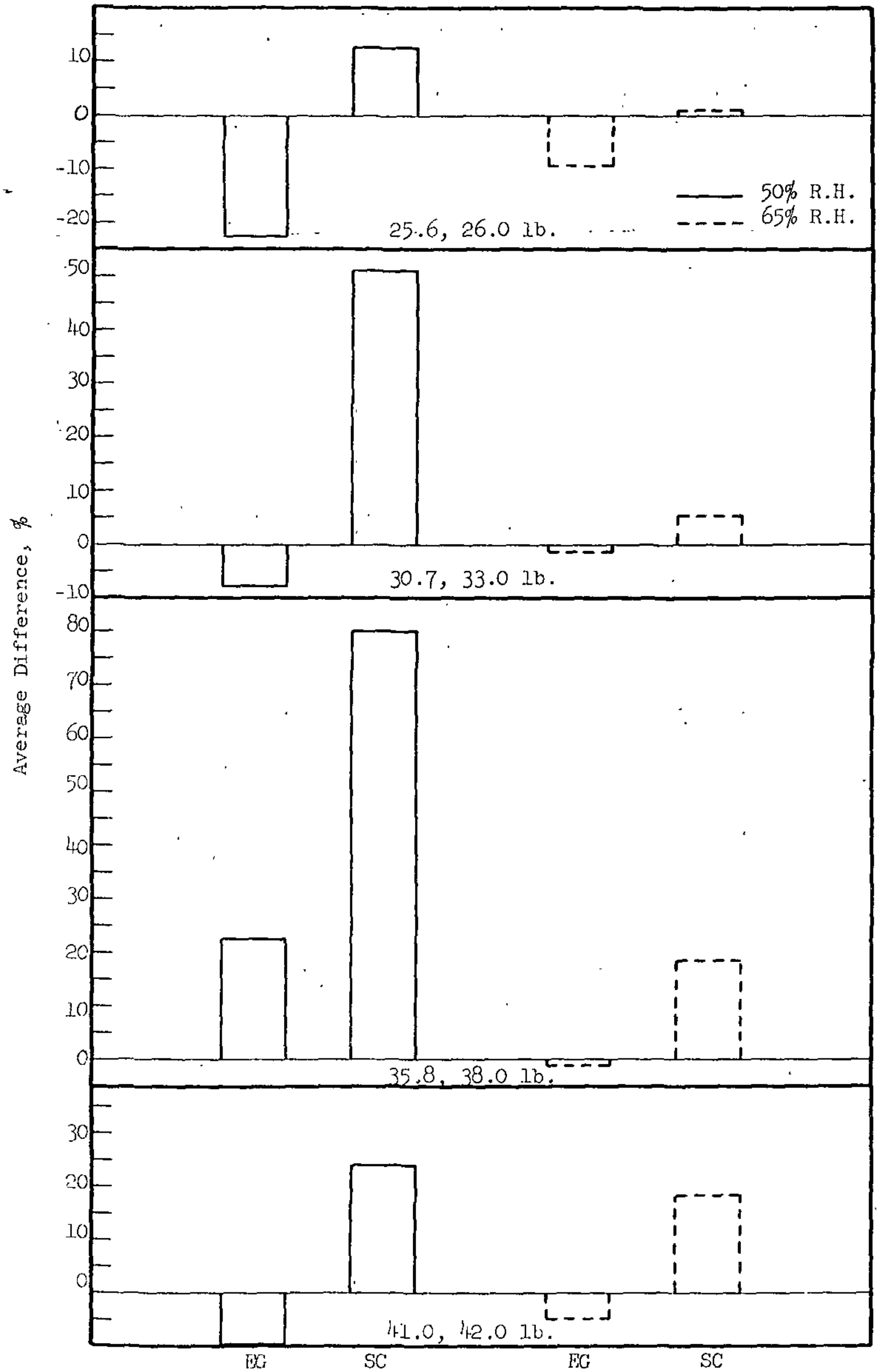


Figure 37. Comparison of Average Difference in Machine-Direction [illegible] Bond Strength of European and U.S. Linerboards

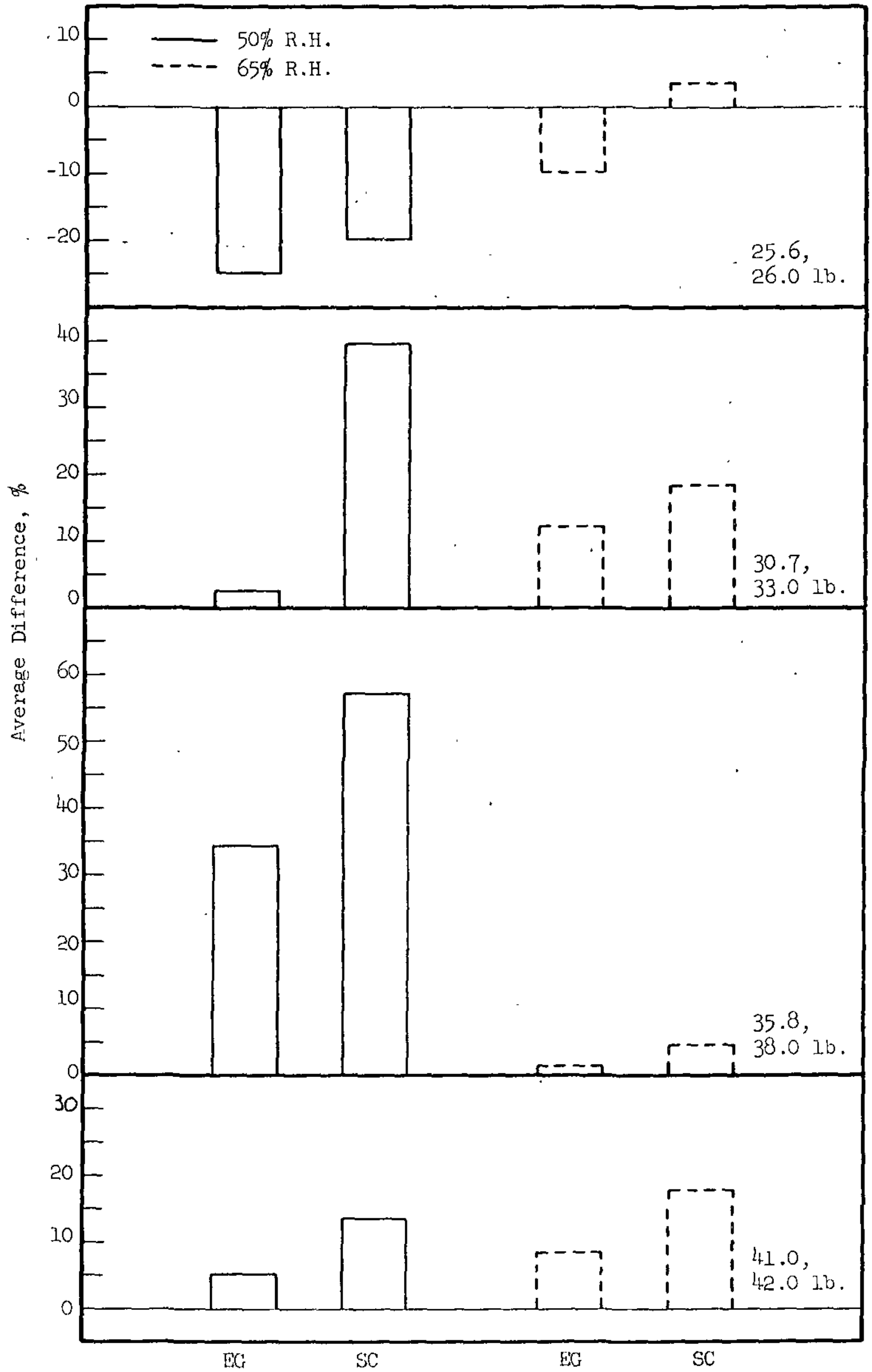


Figure 38. Comparison of Average Difference in Cross-Direction I.P.C. Bond Strength of European and U.S. Linerboards

grade weight levels, however, the European linerboards give higher cross-machine bond strengths.

The porosity of linerboard plays an important role in printing, bonding on the corrugator, in case sealing, etc., and is functionally related to density. The porosity is determined in terms of the time for a given volume of air, 100 cc., to pass through the test specimen; therefore, the higher the time in seconds, the less porous the linerboard. For comparison purposes the average differences in porosity are tabulated as follows (see Tables XXXIII and XXXIV) and are graphically illustrated in Fig. 39:

Nominal Wt., lb./M sq.ft.	Average Difference in Porosity, %[a] 50% R.H. U.S. Linerboard Porosity, sec./100 cc.	E.G.	S.C.	65% R.H. U.S. Linerboard Porosity, sec./100 cc.	E.G.	S.C.
26.0	13	+84.6	+207.7	10	+120.0	+222.0
33.0	38	+257.9	-31.6	31	+303.2	-32.3
38.0	29	+369.0	+120.7	28	+292.9	+96.4
42.0	28	+289.3	+135.7	25	+300.0	+136.0
	Average	+250.2	+108.1		+254.0	+105.5

[a]U.S. linerboard results used as reference.

It may be seen that except for one instance the U.S. linerboards exhibit lower porosity test values and, hence, are more porous than the corresponding European linerboards. Enso Gutseit linerboards generally give higher porosity values than Svenska Cellulosa linerboards. If the porosity values are too high, difficulty may be encountered during fabrication. In fact, in connection with the fabrication of the combined boards made in this study, it was necessary to rerun Run 20 (Enso Gutseit linerboard) because of poor adhesion.

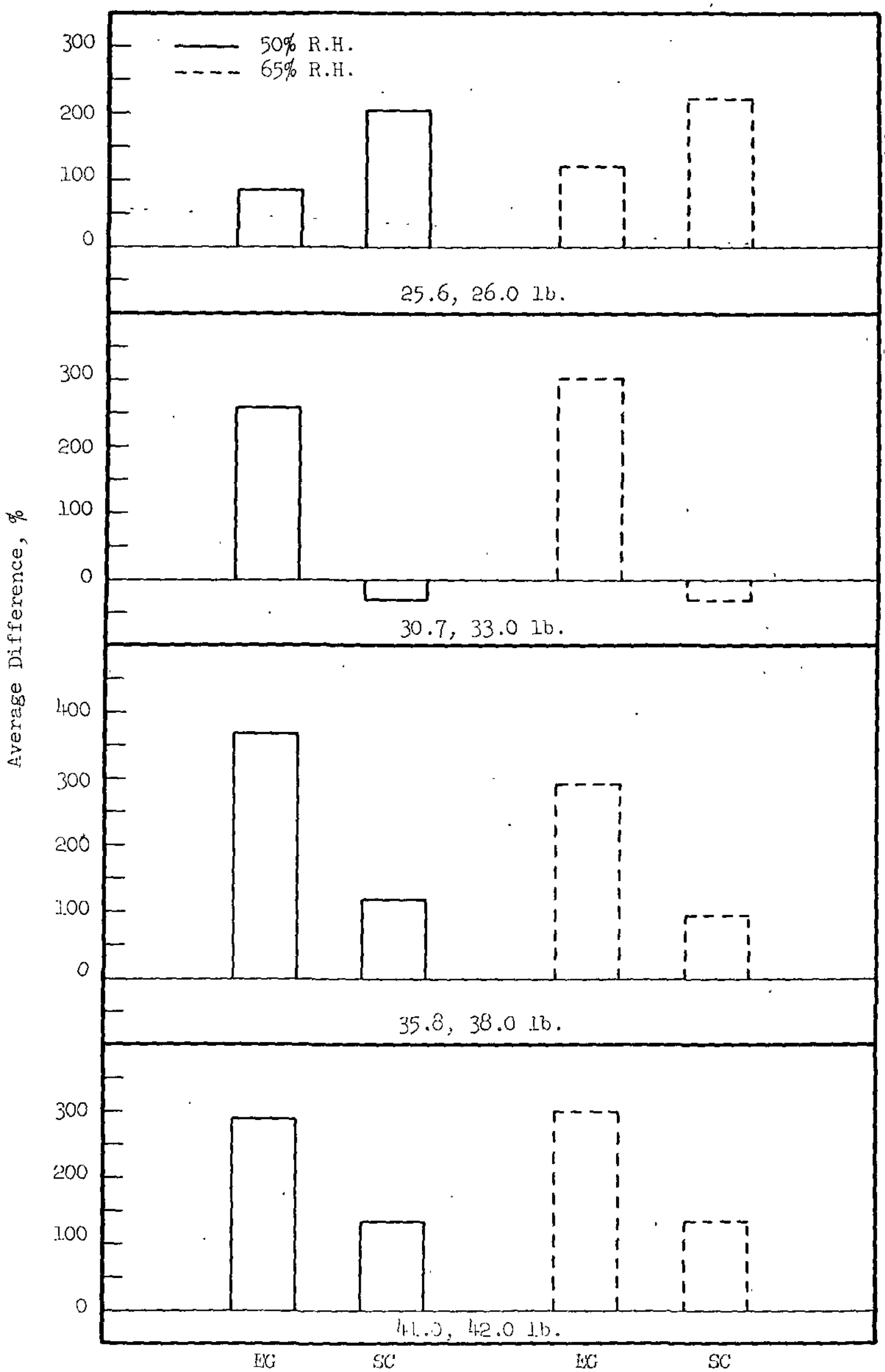


Figure 39. Comparison of Average Difference in Porosity of [illegible] Linerboards

In general, the European linerboards were more difficult to bond because of their high, nonuniform moisture content.

Smoothness, as reported herein, was evaluated by means of a Bendsten smoothness tester in which smoothness is measured in terms of the volume of air which will pass between the top (opposite to wire side) surface of the specimen and the test plate in a given time; the higher the volume, the rougher the specimen.

The average differences in smoothness are as follows (see Tables XXXIII and XXXIV) and are illustrated in Fig. 40:

	Average Difference in Smoothness Test, %[a]					
	50% R.H.			65% R.H.		
Nominal Wt., lb./ M sq.ft.	U.S. Linerboard Smoothness, ml./min.	E.G.	S.C.	U.S. Linerboard Smoothness, ml./min.	E.G.	S.C.
26.0	987	-22.5	-13.1	1108	-27.1	-31.1
33.0	498	+97.6	+66.7	606	+49.7	+44.2
38.0	616	+49.2	-19.2	666	+36.9	-32.4
42.0	700	+36.6	+49.0	692	+42.6	+54.6
	Average	+40.2	+20.8		+25.5	+8.8

[a] U.S. linerboard results used as reference.

It may be seen that the smoothness test results of the U.S. linerboards at the 25.6, 26.0-lb. grade weight level are higher and, hence, the smoothness of U.S. linerboards is lower than that of the European linerboards at this grade weight level. With one exception at the other grade weight levels the smoothness test results are higher on the European linerboard and, hence, they are less smooth than the U.S. linerboards. The one exception is the Svenska Cellulosa linerboard at the 35.7, 38.0-lb. grade weight level.

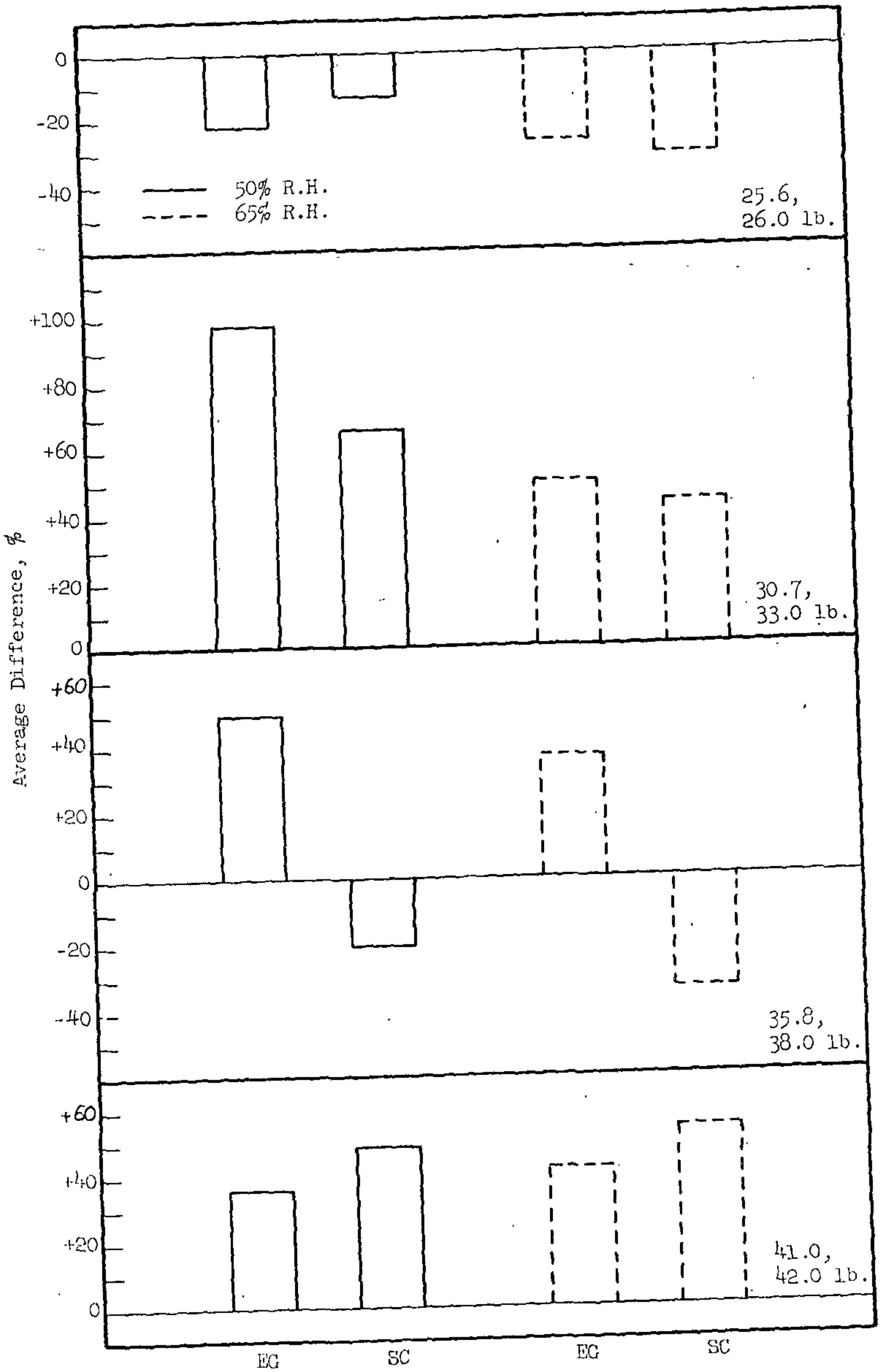


Figure 40. Comparison of Average Difference in Smoothness of European and U.S. Linerboards

The Cobb size test was used to evaluate the degree of sizing. By means of this test the degree of sizing is measured in terms of the amount of moisture picked up when one side of the test specimen is exposed to water for a prescribed time period; thus, the higher the Cobb size value the poorer the sizing. For purposes of comparison, the average differences in Cobb size results are as follows (see Tables XXXIII and XXXIV) and graphically illustrated in Fig. [illegible]:

	Average Difference in Cobb Size, %[a]					
	50% R.H.			65% R.H.		
Nominal Wt., lb./M sq.ft.	U.S. Linerboard Cobb Size, g./sq.m.	E.G.	S.C.	U.S. Linerboard Cobb Size, g./sq.m.	E.G.	S.C.
26.0	38.5	-3.4	-2.9	33.6	[illegible]	+0.6
33.0	35.6	+21.6	+7.6	[illegible]	[illegible]	[illegible]
38.0	36.5	-1.9	+0.3	32.7	[illegible]	-2.1
42.0	33.2	-2.4	+11.4	[illegible]	[illegible]	[illegible]
	Average	+3.5	+4.1		[illegible]	[illegible]

[a]U.S. linerboard results used as reference.

It may be observed that at the 25.6, 26.0-lb. grade weight level, the U.S. linerboard exhibits lower size resistance – i.e., the Cobb size results are higher than those for the corresponding European linerboards. However, the differences are not large enough to be considered significant. It would appear that there is no significant difference in the water resistance as measured by the Cobb size test except for Enso Gutseit linerboard at 30.7, 33.0-lb. grade weight level and Svenska Cellulosa linerboard at 41.0, 42.0-lb. grade weight level. Both these linerboards appear to be lower in water resistance than the corresponding U.S. linerboards.

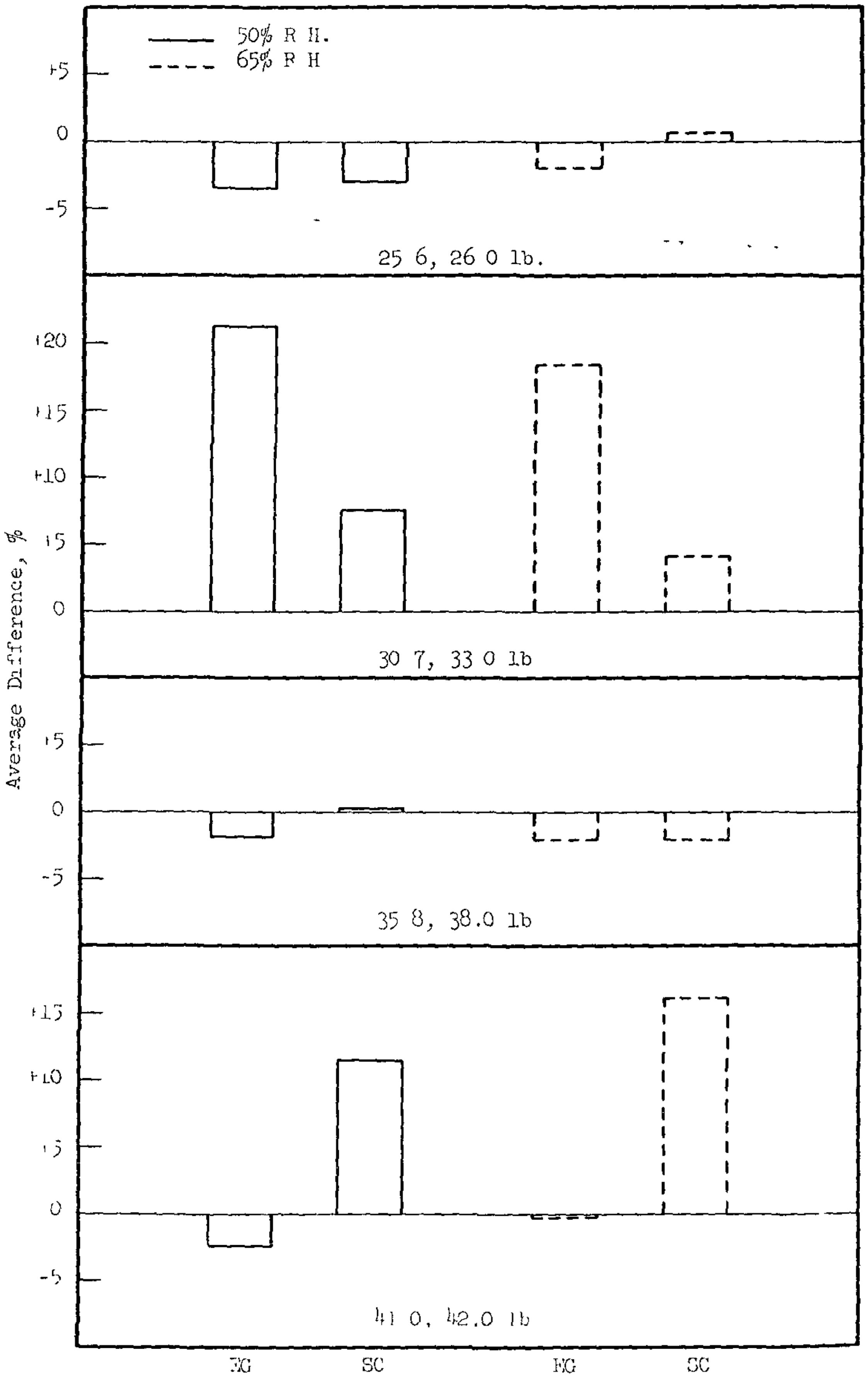


Figure 44 Comparison of Average Difference in Cobb Size of ... and U. S. Linerboards

European linerboard appears to be made from a furnish consisting mainly of Scotch pine, refined to a lower freeness and average fiber length and presumably run at a slower machine speed than U.S. linerboard. The results of this study indicate that the property of European linerboard responsible for their competitive potential is not bursting strength but the level to which the more basic mechanical properties - e.g., edgewise compression, modulus of elasticity, tensile strength, etc. - develop concomitantly with bursting strength. In spite of the lower basis weight, European linerboards used in this study exhibit about equal edgewise compression but markedly higher tensile and modulus of elasticity characteristics than the corresponding U.S. linerboards.

Previous studies have shown that box compression is primarily dependent on two fundamental combined board properties, namely, edgewise compression and flexural stiffness. Further, it has been found that the cross-machine edgewise compression, which is the dominant combined board property in the case of top-load compression, is a function of the cross-machine edgewise compression of the components and to a lesser degree a function of the cross-machine modulus of elasticity of the linerboard. The flexural stiffness of the combined board has been found to be primarily a function of the modulus of the linerboard and the caliper of the combined board. Thus, it should not be surprising that the lower weight European linerboard which exhibits about equal edgewise compression, but markedly higher moduli gives box compression performance in general about equivalent to boxes made with heavier weight U.S. linerboard. On an equal weight basis, boxes made with European linerboard tend to give equal or higher box compression compared to boxes made with U.S. linerboard.

The attainment of markedly higher bursting strength, tensile strength, modulus of elasticity, etc., by the European linerboards at a substantially lower basis weight by means of greater refining – better bonding – is made possible at the expense of fiber length and, hence, tearing strength. The lower tearing strength of the European linerboard is also manifested in lower tearing strength combined board as measured in terms of torsion tear and puncture resistance. It might be anticipated that boxes made with European linerboard would be inferior to boxes made with higher tearing strength U.S. linerboard in terms of such rough handling tests as corner drop and drum performance. It should be emphasized, however, that rough handling performance is dependent on cross-machine tensile and energy absorption, T.E.A., properties as well as tearing strength. In terms of rough handling performance the lower tearing strength of the European linerboards is compensated for, in part at least, by substantially higher tensile and energy absorption characteristics compared to the U.S. linerboards.

In order to compare the uniformity of linerboard from the three sources, the coefficients of variation were determined for a selected number of test properties at 50% R.H. The properties selected were bursting strength, Elmendorf tearing strength, modified ring compression and Taber stiffness. The coefficients of variation are tabulated in Table XXXV. It may be seen that on the basis of the coefficients of variation the U.S. linerboards are generally slightly more uniform than the European linerboards. This is of importance, for example, when considered from the standpoint of Rule 41 which states that only one bursting strength reading out of six (16.7%) may be below the specified level. On the other hand, this particular requirement would not penalize the European linerboards because their average bursting strengths exceed by far the requirements to meet Rule 41.

When the tearing strengths are compared it may be noted that there is very little difference in the coefficients of variation although the U.S.

TABLE XXXV

COMPARISON OF COEFFICIENTS OF VARIATION
(50% Relative Humidity)

Test Property		Nominal Grade Weight Linerboard, lb./M sq. ft.	Coefficient of Variation US Linerboard	EG Linerboard	SC Linerboard
Bursting strength		25.6, 26.0	9.2	7.6	10.5
		30.7, 33.0	6.8	9.7	13.7
		35.8, 38.0	9.3	14.7	10.5
		41.0, 42.0	8.8	13.3	18.2
Elmendorf tearing strength	M.D.	25.6, 26.0	6.4	7.4	9.8
		30.7, 33.0	8.3	8.9	8.5
		35.8, 38.0	8.6	9.7	7.2
		41.0, 42.0	8.5	11.2	9.5
	C.D.	25.6, 26.0	5.5	6.8	6.2
		30.7, 33.0	4.6	5.0	8.1
		35.8, 38.0	5.2	5.4	4.7
		41.0, 42.0	5.9	7.5	7.4
Modified ring compression	M.D.	25.6, 26.0	6.9	8.6	8.1
		30.7, 33.0	6.7	7.4	7.8
		35.8, 38.0	7.7	5.4	6.5
		41.0, 42.0	5.8	6.7	8.1
	C.D.	25.6, 26.0	5.8	6.9	6.1
		30.7, 33.0	6.9	6.8	8.8
		35.8, 38.0	7.5	6.5	7.8
		41.0, 42.0	5.4	5.5	7.1
Taber stiffness	M.D.	25.6, 26.0	7.5	7.1	10.5
		30.7, 33.0	5.1	9.9	11.9
		35.8, 38.0	6.1	9.4	5.2
		41.0, 42.0	4.3	7.3	8.7
	C.D.	25.6, 26.0	9.8	12.6	16.1
		30.7, 33.0	11.5	12.7	11.6
		35.8, 38.0	7.2	12.7	13.7
		41.0, 42.0	9.2	11.4	12.9

linerboards have a very slight advantage in uniformity. The same general trend is also shown by the modified ring compression results.

In general, the U.S. linerboards exhibit slightly better uniformity in terms of Taber stiffness than the European linerboards. The Enso Gutseit linerboards, in turn, generally exhibit greater uniformity than the Svenska Cellulosa linerboards.

II. CORRUGATING MEDIUM RESULTS

It may be recalled that each of the domestic and European linerboards was fabricated with both 26-lb. U.S. semichemical and 23-lb. European semichemical corrugating medium into A-flute and B-flute combined boards and boxes. In addition to these mediums, all the U.S. linerboards were also fabricated with 26-lb. European semichemical medium into A-flute combined board and boxes.

The 23-lb. European medium was made from a furnish consisting of approximately 85% hardwood (birch) and 15% softwood (mainly Scotch pine) refined to a substantially lower average fiber length than the 26-lb. U.S. medium which was made from a furnish consisting of approximately 85% hardwood (gum) and 15% softwood (southern pine).

A. Comparative Performance of Boxes Fabricated with U.S. and European Mediums

1. Compression Performance

In order to compare the effect of the type of medium on box compressio performance, the box compression results have been recompiled to facilitate this comparison and are given in Tables XXXVI and XXXVII for 50 and 65% R.H., respectively, and graphically illustrated in Fig. 42a. The data given in Tables XXXVI and XXXVII have been analyzed statistically to determine whether the observed

TABLE XXXVI

EFFECT OF TYPE OF MEDIUM ON COMPRESSION PERFORMANCE
(50% Relative Humidity)

		Top-Load Compression (0-0.75 in.), lb.						End-Load Compression (0-0.50 in.), lb.					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %
3, 4	26.0-lb. U.S.	530	565	+ 6.6	460	465	+ 1.1	270	255	- 5.6	330	330	0.0
2, 1	25.6-lb. E.G.	510	520	+ 2.0	445	435	- 2.2	245	230	- 6.1	340	320	- 5.9
6, 5	25.6-lb. S.C.	520	530	+ 1.9	440	435	- 1.1	255	255	0.0	345	320	- 7.2
Composite		520	538	+ 3.5	448	445	- 0.7	257	247	- 3.9	338	323	- 4.4
10, 9	33.0-lb. U.S.	595	590	- 0.8	545	545	0.0	345	350	+ 1.4	480	420	-12.5
7, 8	30.7-lb. E.G.	615	595	- 3.3	545	555	+ 1.8	350	335	- 4.3	410	415	+ 1.2
11, 12	30.7-lb. S.C.	610	625	+ 2.5	525	515	- 1.9	340	355	+ 4.4	440	415	- 5.7
Composite		607	603	- 0.7	538	538	0.0	345	347	+ 0.6	443	417	- 5.9
15, 16	38.0-lb. U.S.	635	660	+ 3.9	565	560	- 0.9	400	400	0.0	535	460	-14.0
14, 13	35.8-lb. E.G.	690	675	- 2.2	600	635	+ 5.8	405	415	+ 2.5	520	495	- 4.8
18, 17	35.8-lb. S.C.	640	630	- 1.6	590	585	- 0.8	385	390	+ 1.3	435	425	- 2.3
Composite		655	655	0.0	585	593	+ 1.4	397	402	+ 1.3	497	460	- 7.4
23, 24	42.0-lb. U.S.	730	725	- 0.7	600	575	- 4.2	455	440	- 3.3	590	535	- 9.3
19, 20	41.0-lb. E.G.	775	815	+ 5.2	640	630	- 1.6	470	485	+ 3.2	610	600	- 1.6
22, 21	41.0-lb. S.C.	715	740	+ 3.5	640	650	+ 1.6	495	490	- 1.0	535	575	+ 7.5
Composite		740	760	+ 2.7	627	618	- 1.4	473	472	- 0.2	578	570	- 1.4

[a] U. S. 26.0-lb. medium used as reference.

TABLE XXXVII

EFFECT OF TYPE OF MEDIUM ON COMPRESSION PERFORMANCE
(65% Relative Humidity)

Run	Nominal Liner Weight	Top-Load Compression (0-0.75 in.), lb.						End-Load Compression (0-0.50 in.), lb.					
		A-Flute			B-Flute			A-Flute			B-Flute		
		U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %
3, 4	26.0-lb. U.S.	490	520	+ 6.1	405	450	+11.1	235	225	- 4.3	310	290	- 6.5
2, 1	25.6-lb. E.G.	465	515	+10.8	425	420	- 1.2	210	220	+ 4.8	305	280	- 8.2
6, 5	25.6-lb. S.C.	470	455	- 3.2	405	395	- 2.5	235	220	- 6.4	305	305	0.0
Composite		475	497	+ 4.6	412	422	+ 2.4	227	222	- 2.2	307	292	- 4.9
10, 9	33.0-lb. U.S.	560	540	- 3.6	495	500	+ 1.0	330	305	- 7.6	420	395	- 6.0
7, 8	30.7-lb. E.G.	540	545	+ 0.9	510	480	- 5.9	305	305	0.0	355	385	+ 8.5
11, 12	30.7-lb. S.C.	545	575	+ 5.5	495	470	- 5.1	305	335	+ 9.8	415	380	- 8.4
Composite		548	553	+ 0.9	500	483	- 3.4	313	315	+ 0.6	397	387	- 2.5
15, 16	38.0-lb. U.S.	600	600	0.0	535	510	- 4.7	360	345	- 4.2	480	445	- 7.3
14, 13	35.8-ln. E.G.	605	610	+ 0.8	570	620	+ 8.8	370	400	+ 8.1	485	475	- 2.1
18, 17	35.8-lb. S.C.	625	615	- 1.6	570	525	- 7.9	340	350	+ 2.9	455	370	-18.7
Composite		610	608	- 0.3	558	552	- 1.1	357	365	+ 2.2	473	430	- 9.1
23, 24	42.0-lb. U.S.	670	675	+ 0.7	570	515	- 9.6	420	410	- 2.4	540	550	+ 1.9
19, 20	41.0-lb. E.G.	750	735	- 2.0	620	600	- 3.2	440	470	+ 6.8	555	540	- 2.7
22, 21	41.0-lb. S.C.	685	625	- 8.8	580	580	0.0	430	430	0.0	555	530	- 4.5
Composite		702	678	- 3.4	590	565	- 4.2	430	437	+ 1.6	550	540	- 1.8

[a] U.S. 26.0-lb. medium used as reference.

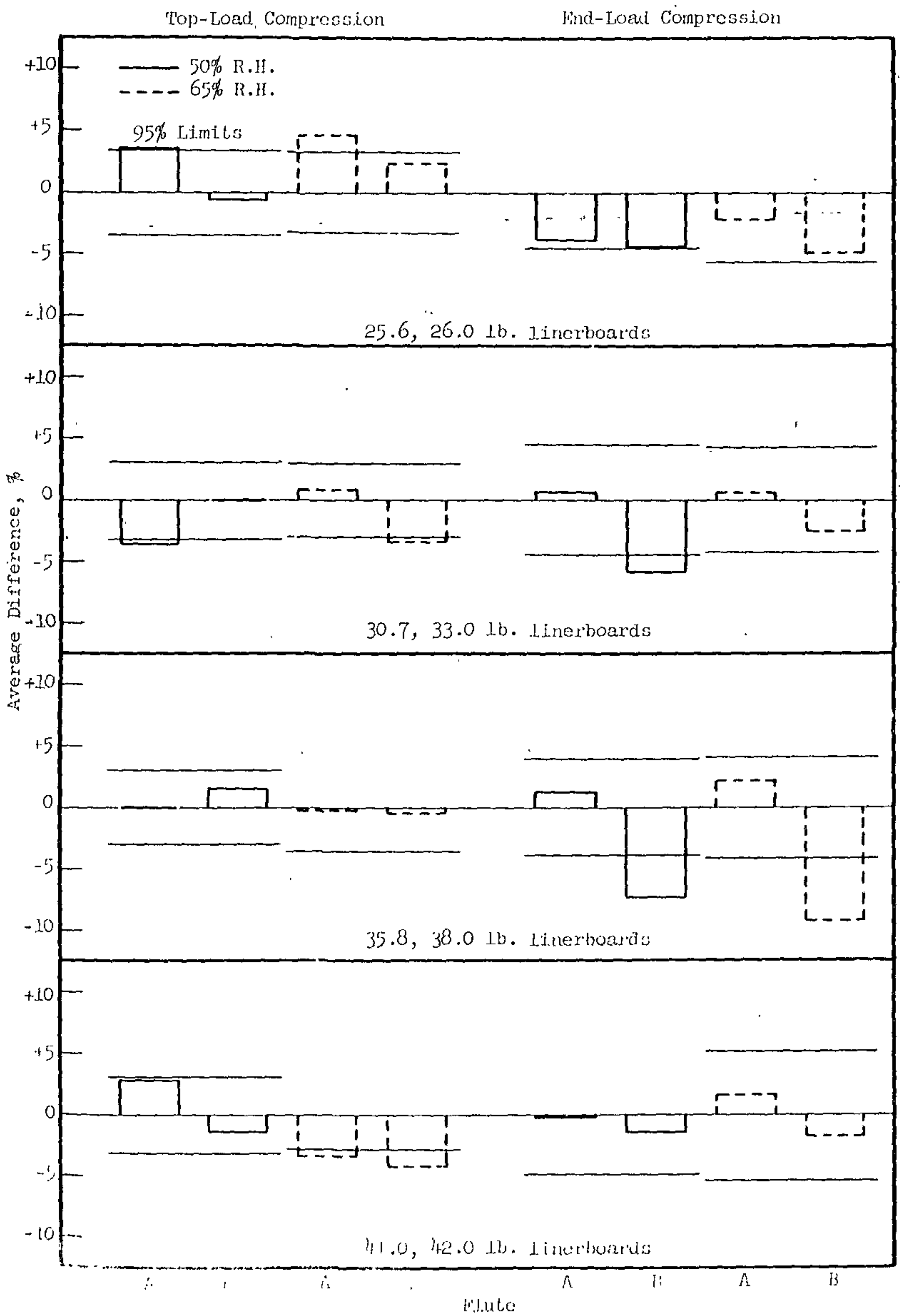


Figure 42a. [illegible] of Type [illegible] (26-lb. U.S. as Reference vs. 33-lb. European) on Average Difference in Box [illegible]

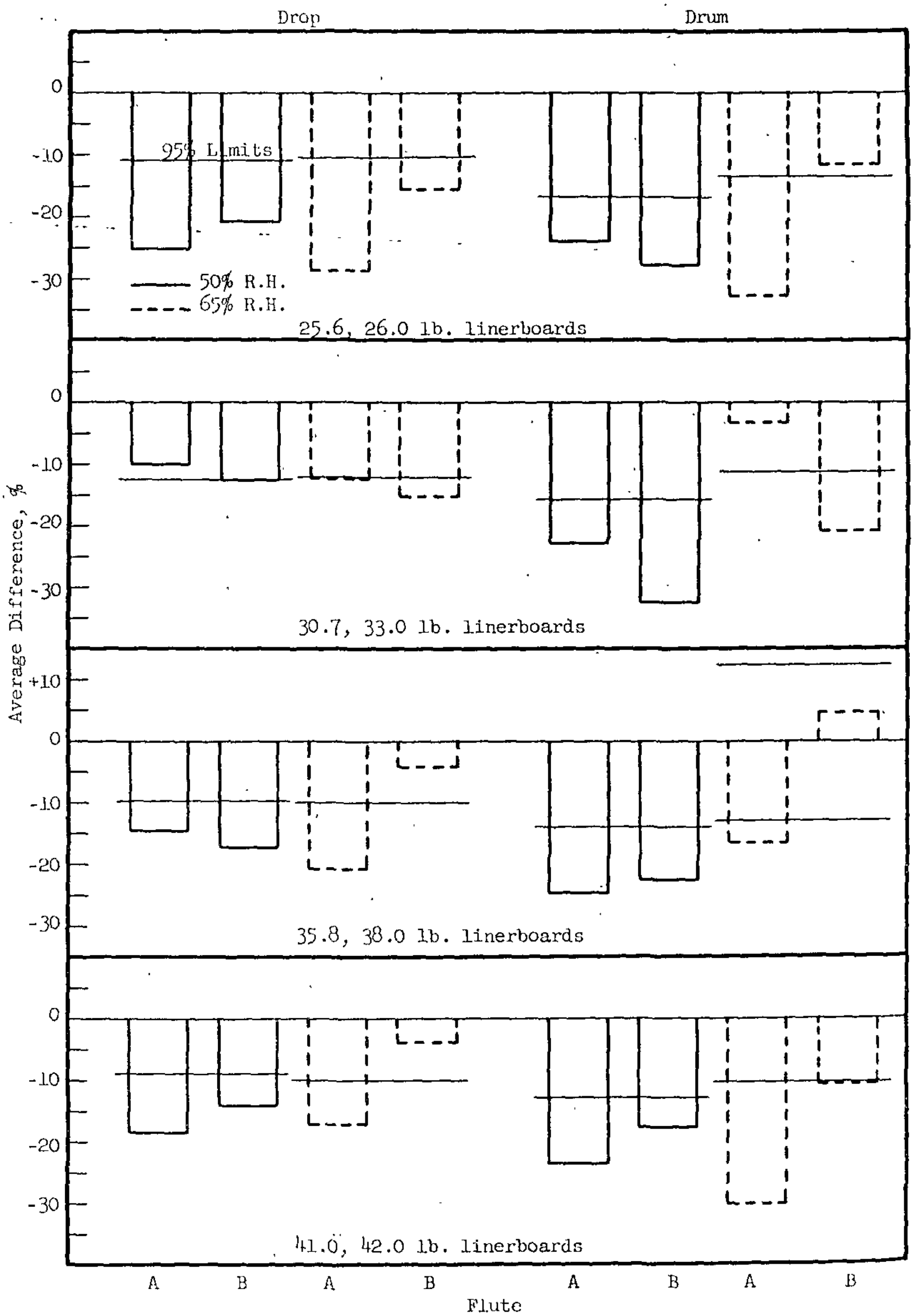


Figure 42b. Comparison of the Effect of Type of Medium (26-Lb. U.S. as Reference vs. 23-Lb. European) on Average Difference in Rough Handling Performance

composite average differences represent real differences or could have occurred by chance. The statistically determined levels of significance for the composite average differences are shown in Table XXXVIII. The figure in parentheses following each average indicates the level of confidence at which the difference is significant. The symbol NS signifies that the difference is not significant at the 5% level of confidence.

It may be seen from the composite average differences tabulated in Table XXXVIII, together with the assessment of the statistical significance of the observed composite average differences that, in general, there is no difference in box compression associated with the type of medium except in a few cases. One of the exceptions is top-load A-flute compression at the 25.6, 26.0-lb. linerboard grade weight level, wherein the results show that boxes made with 23.0-lb. European medium give higher top-load compression loads than boxes made with 26.0-lb. U.S. medium. In all other instances, where the composite average differences were statistically significant, higher results were obtained with the boxes made with 26.0-lb. U.S. medium. Except for the one case noted, therefore, the boxes made with 23.0-lb. European medium exhibit equal or lower compression results. In all other cases where significant differences were observed, the differences were less than 10% and in most instances less than 5%.

It should be borne in mind in interpreting these results that reducing the nominal weight of the medium from 26.0 to 23.0 pounds results in a weight reduction of approximately 11.5%. Accordingly, in order to compare the compression performance on an equal weight basis the results tabulated in Tables XXXVI and XXXVII have been divided by the corresponding combined board weight and are tabulated in Tables XXXIX and XL on a performance per unit combined board weight basis and illustrated in Fig. 43. The composite average differences are also

TABLE XXXVIII

COMPOSITE AVERAGE DIFFERENCE DUE TO TYPE OF CORRUGATING MEDIUM

[illegible] Humidity, %	Composite Average Differences on Box Basis[a]								Composite Average Differences on Unit Combined Board Basis[a]							
	Top-Load Compression Difference, %		End-Load Compression Difference, %		Drop Performance Difference, %		Drum Performance Difference, %		Top-Load Compression Difference, %		End-Load Compression Difference, %		Drop Performance Difference, %		Drum Performance Difference, %	
	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute	A-Flute	B-Flute
25.6, 26.0-lb. Linerboard																
50	-3.5(.05)	-0.7(NS)	-3.9(NS)	-1.4(.05)	-25.3(.01)	-20.7(.01)	-24.2(.01)	-27.8(.05)	+ 8.6	+ 4.0	+ 1.2	+ 0.3	-22.6	-16.4	-20.3	-24.1
65	+4.6(.01)	+2.4(NS)	-2.2(NS)	-4.9(NS)	-28.6(.01)	-15.7(.01)	-32.9(.01)	-11.5(NS)	+ 9.4	+ 8.0	+ 2.2	+ 0.6	-25.2	-11.6	-29.8	- 7.4
30.7, 33.0-lb. Linerboard																
50	-0.7(NS)	0.0(--)	-0.6(NS)	-5.9(.01)	-10.3(NS)	-12.5(NS)	-22.9(.01)	-32.4(.01)	+ 3.6	+ 5.3	+ 4.4	- 1.0	- 5.5	- 7.4	-19.2	-28.4
65	+0.9(NS)	-3.4(.05)	+0.6(NS)	-2.5(NS)	-12.2(.01)	-15.1(.01)	- 3.1(NS)	-20.8(.05)	+ 5.5	+ 0.4	+ 5.0	+ 1.4	- 7.7	-12.2	+ 2.3	-16.9
35.8, 38.0-lb. Linerboard																
50	0.0(--)	+1.4(NS)	+1.3(NS)	-7.4(.01)	-14.6(.01)	-17.2(.01)	-24.8(.01)	-22.6(.05)	+ 4.4	+ 7.1	+ 5.8	- 2.3	-10.8	-12.8	-21.4	-19.8
65	-0.3(NS)	-1.1(NS)	+2.2(NS)	-9.1(.05)	-20.6(.01)	- 4.2(NS)	-16.5(.01)	+ 4.7(NS)	+ 3.6	+ 3.6	+ 6.6	- 5.2	-18.3	0.0	-12.4	+ 8.2
41.0, 42.0-lb. Linerboard																
50	+2.7(NS)	-1.4(NS)	-0.2(NS)	-1.4(NS)	-16.3(.01)	-13.9(.01)	-23.4(.01)	-17.6(.05)	+ 6.4	+ 1.8	+ 3.2	+ 1.7	-14.7	-10.8	-20.2	-13.5
65	-3.4(.05)	-4.2(.01)	+1.6(NS)	-1.8(NS)	-17.0(.01)	- 3.8(NS)	-30.1(.01)	-10.5(NS)	+ 0.6	+ 0.9	+ 5.8	+ 3.4	-14.1	+ 1.9	-27.3	- 4.8

[a] Based on results for 26-lb. U.S. medium as reference. Minus prefix means 26-lb. U.S. higher; plus prefix means 26-lb. U.S. lower.

TABLE XXIX

EFFECT OF TYPE OF MEDIUM ON COMPRESSION PERFORMANCE PER UNIT WEIGHT

(50% Relative Humidity)

		Top-Load Compression, lb /100-lb Combined Board Weight						End-Load Compression, lb /100-lb Combined Board Weight					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	U S 26-lb Medium	Eur 23-lb Medium	Diff, %[a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, %[a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, %[a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, %[a]
3, 4	26.0-lb U S	520	583	+12.1	489	511	+4.5	265	263	-0.8	351	363	+3.4
2, 1	25.6-lb E G	515	553	+7.4	473	489	+3.4	247	245	-0.8	362	360	-0.6
6, 5	25.6-lb S C	536	570	+6.3	469	489	+4.3	263	274	+4.2	367	359	-2.2
Composite		524	569	+8.6	477	496	+4.0	258	261	+1.2	360	361	+0.3
10, 9	33.0-lb U S	522	542	+3.8	491	514	+4.7	303	321	+5.9	432	396	-8.3
7, 8	30.7-lb E G	569	572	+0.5	519	555	+6.9	324	322	-0.6	390	415	+6.4
11, 12	30.7-lb S C	570	607	+6.5	505	526	+4.2	318	345	+8.5	423	423	0.0
Composite		554	574	+3.6	505	532	+5.3	315	329	+4.4	415	411	-1.0
15, 16	38.0-lb U S	516	559	+8.3	475	496	+4.4	325	339	+4.3	450	407	-9.6
14, 13	35.5-lb E G	580	592	+2.1	526	583	+10.8	340	364	+7.1	456	454	-0.4
18, 17	35.8-lb S C	542	558	+3.0	518	547	+5.6	326	345	+5.8	382	397	+3.9
Composite		546	570	+4.4	506	542	+7.1	330	349	+5.8	429	419	-2.3
23, 24	42.0-lb U S	562	575	+2.3	476	479	+0.6	350	349	-0.3	468	446	-4.7
19, 20	41.0-lb E G	605	663	+9.6	525	529	+0.8	367	394	+7.4	500	504	+0.8
22, 21	41.0-lb S C	577	617	+6.9	542	560	+3.3	399	408	+2.3	453	496	+9.5
Composite		581	618	+6.4	514	523	+1.8	372	384	+3.2	474	482	+1.7

[a] U.S. 26.0-lb. medium used as reference

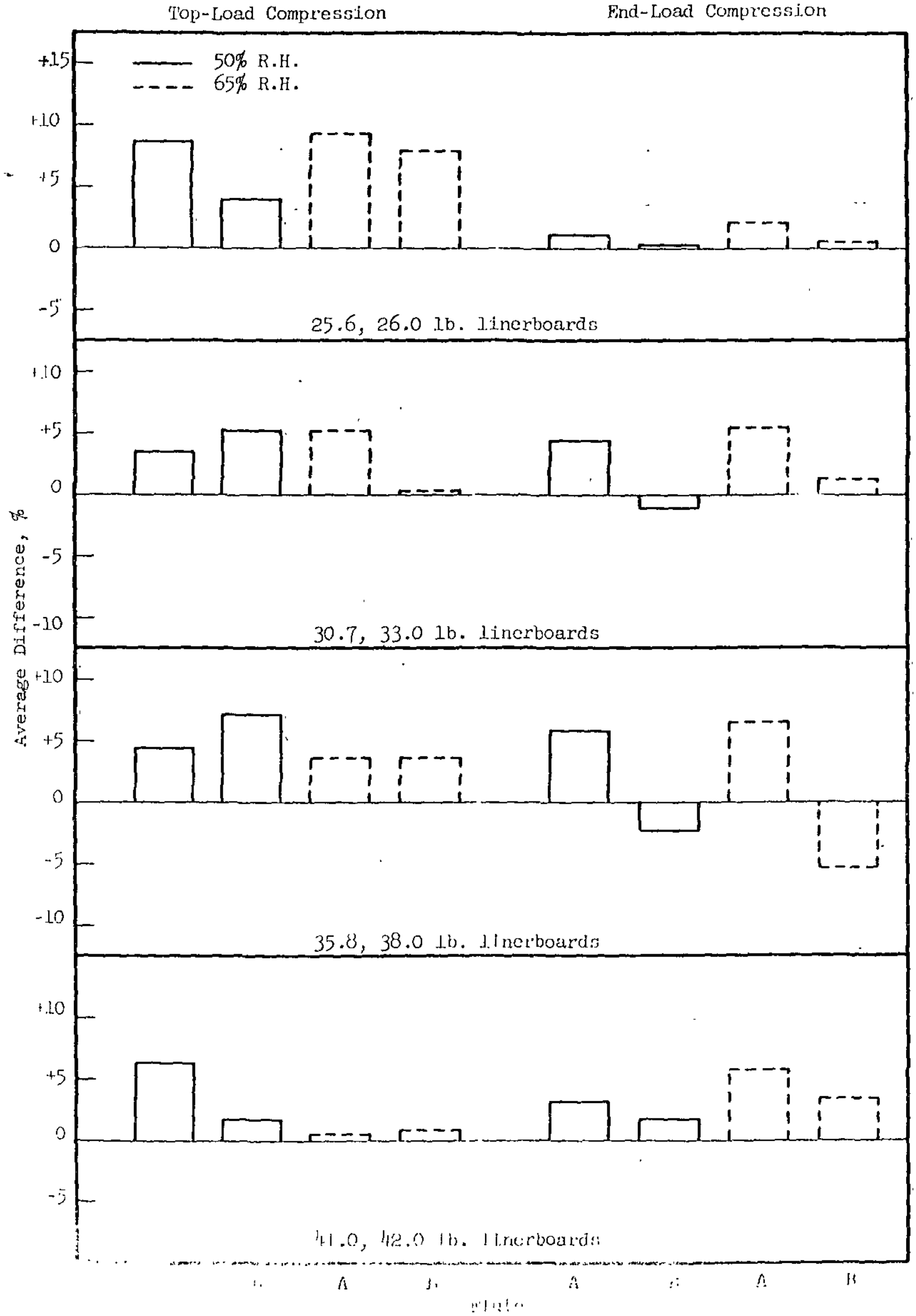
TABLE XL

EFFECT OF TYPE OF MEDIUM ON COMPRESSION PERFORMANCE PER UNIT WEIGHT

(65% Relative Humidity)

		Top-Load Compression, lb /100-lb Combined Board Weight						End-Load Compression, lb /100-lb Combined Board Weight					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	U S 26-lb Medium	Eur 23-lb Medium	Diff , % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff , % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff , % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff , % [a]
3, 4	26 0-lb U S	471	525	+11 5	413	479	+16 0	226	227	+ 0 4	316	309	- 2 2
[illegible]	25 6-lb E G	460	536	+16 5	443	462	+ 4 3	208	229	+10 1	318	308	- 3 1
6, 5	25 6-lb S C	475	479	+ 0 8	422	439	+ 4 0	237	232	- 2 1	318	339	+ 6 6
Composite		469	513	+ 9 4	426	460	+ 8 0	224	229	+ 2 2	317	319	+ 0 6
10, 9	33 0-lb U S	483	482	- 0 2	438	455	+ 3 9	284	272	- 4 2	372	359	- 3 5
7, 8	30 7-lb E G	486	509	+ 4 7	481	471	- 2 1	275	285	+ 3 6	335	377	+12 5
11, 12	30 7-lb S C	495	553	+11.7	467	465	- 0 4	277	322	+16 2	392	376	- 4 1
Composite		488	515	+ 5 5	462	464	+ 0 4	279	293	+ 5 0	366	371	+ 1 4
15, 16	38 0-lb U S	476	492	+ 3 4	442	443	+ 0 2	286	283	- 1 0	397	387	- 2 5
14, 13	35 8-lb E G	492	521	+ 5 9	491	554	+12.8	301	342	+13 6	418	424	+ 1 4
16, 17	35 8-lb S C	521	530	+ 1 7	496	482	- 2 8	283	302	+ 6 7	396	339	-14 4
Composite		496	514	+ 3 6	476	493	+ 3 6	290	309	+ 6 6	404	383	- 5 2
23, 24	42 0-lb U S	504	527	+ 4 6	445	422	- 5 2	316	320	+ 1 3	422	451	+ 6 9
19, 20	41 0-lb E G	573	579	+ 1 0	492	496	+ 0 8	336	370	+10 1	440	446	+ 1 4
22, 21	41 0-lb S C	531	512	+ 3 6	472	504	+ 6 8	333	352	+ 5 7	451	461	+ 2 2
Composite		536	539	+ 0 6	470	474	+ 0 9	328	347	+ 5 8	438	453	+ 3 4

[a] U S 26 0-lb medium used as reference


Top-Load Compression
End-Load Compression
50% R.H.
65% R.H.
Average Difference, %
+15
+10
+5
0
-5
-10
25.6, 26.0 lb. linerboards
30.7, 33.0 lb. linerboards
35.8, 38.0 lb. linerboards
41.0, 42.0 lb. linerboards
A
A
A
B

[illegible]

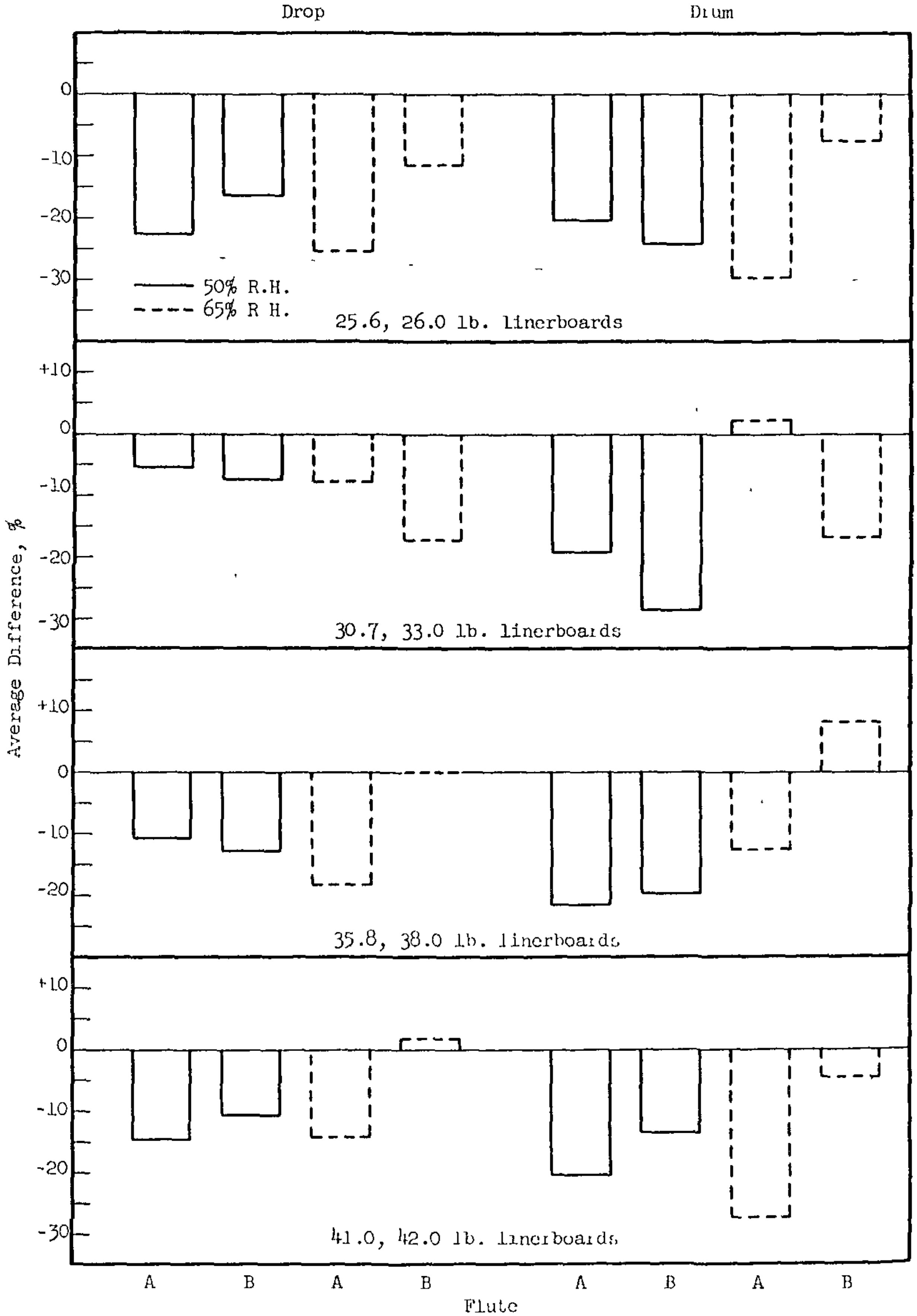


Figure 43b Comparison of the Effect of Type of Medium (26-Lb. U.S. as Reference vs 23-Lb. European) on Average Difference in Rough Handling Performance on Equal Weight Basis

tabulated in Table XXXVIII. It may be noted that on an equivalent combined board weight basis, in practically all cases, the boxes made with 23.0-lb. European medium exhibited higher top-load compression than boxes made with 26.0-lb. U.S. medium. The composite average differences range from 0.4 to 9.4%. Statistical analysis was not carried out on the results calculated on a unit weight basis; however, it is believed that all differences greater than approximately 3.5% probably represent significant differences. When end-load compression results are compared, it may be seen that converting to a unit weight basis has the effect of improving the performance of the boxes made with 23.0-lb. European medium. On this basis, end-load compression results are generally slightly higher for boxes made with 23.0-lb. European medium. On an over-all unit weight basis, boxes made with 23.0-lb. European medium exhibit 4-5% higher top-load compression than boxes made with 26.0-lb. U.S. medium. In the case of end-load the results are mixed; the A-flute results on boxes made with 23.0-lb. European medium are approximately 4% higher than, and the B-flute results are approximately equal to the results on boxes made with 26.0-lb. U.S. medium.

2. Rough Handling Performance

A comparison of the effect of the type of medium on rough handling as measured in terms of corner drop and drum performance may be seen from the results tabulated in Tables XLI and XLII for 50 and 65% R.H., respectively, and illustrated in Fig. 42. These results were statistically analyzed and the composite average differences, together with an estimate of the significance of the difference, are tabulated in Table XXXVIII. On the basis of composite averages, with one exception, boxes made with 23.0-lb. European medium give lower drop and drum performance than boxes made with 26.0-lb. U.S. medium. Further, the magnitude of the difference is such that in most cases the differences are statistically significant; thus, it appears that the 26.0-lb. U.S. medium is

TABLE XLI

EFFECT OF TYPE OF MEDIUM ON ROUGH HANDLING PERFORMANCE
(50% Relative Humidity)

		Corner Drop, Drops to Failure						Drum, Falls to Failure					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	U S 26-lb Medium	Eur 23-lb Medium	Diff, % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, % [a]	U S 26-lb Medium	Eur 23-lb Medium	Diff, % [a]
3, 4	26 0-lb U S	9 1	6 6	-27 4	6 2	4 8	-22.5	84	67	-20 2	56	45	-19 6
2, 1	25 6-lb E G	9 4	6 9	-26 6	6 1	5 1	-16 4	77	45	-41 6	56	48	-14 3
6, 5	25 6-lb S C	6 5	5 0	-23 0	5 0	3 8	-24 0	75	67	-10 7	51	25	-51 0
Composite		8 3	6 2	-25 3	5 8	4 6	-20 7	79	60	-24 1	54	39	-27 8
10, 9	33 0-lb. U S.	10 1	8 7	-13.9	6 5	5.6	-13 8	110	110	0.0	63	42	-33 3
7, 8	30 7-lb E G	9.4	7 8	-17 0	6 8	6 6	- 2 9	99	56	-43 4	62	43	-30 6
11, 12	30 7-lb S C.	10 5	10.5	0 0	8 2	6 8	-17 1	118	87	-26 3	87	60	-31 0
Composite		10 0	9.0	-10.0	7 2	6 3	-12 5	109	84	-22.9	71	48	-32 4
15, 16	38 0-lb U S	12.2	11.6	- 4 9	10 1	8 2	-18 8	154	120	-22 1	88	74	-15 9
14, 13	35 8-lb E G.	10 8	8 9	-17.6	8 5	7 7	- 9 4	122	91	-25 4	76	68	-10 5
18, 17	35 8-lb S C	13 8	11 0	-20.3	11 2	8 7	-22 3	146	106	-27 4	116	74	-36 2
Composite		12 3	10 5	-14 6	9 9	8.2	-17.2	141	106	-24 8	93	72	-22 6
23, 24	42 0-lb U S	13.3	10 4	-21 8	9.9	8.0	-19.2	144	110	-23.6	94	77	-18 1
19, 20	41 0-lb E.G	13 2	11 5	-12.9	9 6	9.2	- 4 2	151	107	-29 1	96	54	-43 8
22, 21	41 0-lb S C	12 7	10 1	-20 5	10 7	8 9	-16 8	141	116	-16 1	82	95	+15 9
Composite		13 1	10 7	-18 3	10 1	8 7	-13 9	145	111	-23 4	91	75	-17.6

[a] U S 26 0-lb medium used as reference

TABLE XLIII

EFFECT OF TYPE OF MEDIUM ON ROUGH HANDLING PERFORMANCE
(65% Relative Humidity)

		Corner Drop, Drops to Failure						Drum, Falls to Failure					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %	U.S. 26-lb. Medium	Eur. 23-lb. Medium	Diff.,[a] %
3, 4	26.0-lb. U.S.	11.4	8.1	-28.9	8.6	6.9	-19.8	92	62	-32.6	52	51	- 1.9
2, 1	25.6-lb. E.G.	11.3	8.6	-23.9	9.2	7.3	-20.7	82	55	-32.9	55	54	- 1.8
6, 5	25.6-lb. S.C.	10.9	7.4	-32.1	7.1	6.8	- 4.2	81	53	-34.6	50	33	-34.0
Composite		11.2	8.0	-28.6	8.3	7.0	-15.7	85	57	-32.9	52	46	-11.5
10, 9	33.0-lb. U.S.	13.0	10.4	-20.0	9.1	8.9	- 2.2	99	106	+ 7.1	80	55	-31.3
7, 8	30.7-lb. E.G.	12.0	10.1	-15.8	10.6	9.2	-13.2	93	78	-16.1	65	52	-20.0
11, 12	30.7-lb. S.C.	14.4	14.1	- 2.1	12.0	8.8	-26.2	102	102	0.0	86	76	-11.6
Composite		13.1	11.5	-12.2	10.6	9.0	-15.1	98	95	- 3.1	77	61	-20.8
15, 16	38.0-lb. U.S.	13.6	11.7	-14.0	12.2	10.8	-11.5	150	118	-21.3	94	94	0.0
14, 13	35.8-lb. E.G.	14.3	12.9	- 9.8	9.9	11.3	+14.1	105	105	0.0	75	80	+ 6.7
18, 17	35.8-lb. S.C.	20.1	13.4	-33.3	14.0	12.4	-11.4	162	126	-22.2	87	92	+ 5.7
Composite		16.0	12.7	-20.6	12.0	11.5	- 4.2	139	116	-16.5	85	89	+ 4.7
23, 24	42.0-lb. U.S.	15.9	12.9	-18.9	11.9	11.7	- 1.7	185	153	-17.3	104	98	- 5.8
19, 20	41.0-lb. E.G.	18.4	13.5	-26.6	13.9	11.9	-14.4	154	97	-37.0	110	92	-16.4
22, 21	41.0-lb. S.C.	18.6	17.3	- 7.0	13.1	13.8	+ 5.3	179	113	-36.9	101	93	- 7.9
Composite		17.6	14.6	-17.0	13.0	12.5	- 3.8	173	121	-30.1	105	94	-10.5

[a] U.S. 26.0-lb. medium used as reference.

better than 23.0-lb. European medium for rough handling performance as measured in terms of drop and drum tests and expressed on a box basis.

As previously pointed out, reducing the nominal grade weight of the medium from 26.0 to 23.0 pounds consistutes approximately a 11.5% reduction in medium weight. In order to compare rough handling performance on an equivalent weight basis the results tabulated in Tables XLI and XLII have been converted to rough handling performance per unit combined board weight. The results on a unit weight basis are tabulated in Tables XLIII and XLIV and illustrated in Fig. 43. The composite average difference at the various levels of linerboard weight are also tabulated in Table XXXVIII. The same general trend may be observed, that is, boxes made with 23.0-lb. European medium are lower in rough handling performance than boxes made with 26.0-lb. U.S. medium. It may be noted, however, that in general the differences on a unit weight basis are less, as would be expected, than on the observed box basis. Further, it is questionable whether the differences obtained on a unit weight basis represent real differences except in a few instances - e.g., at the 25.6, 26.0-lb. linerboard grade weight level.

It may be recalled that each of the U.S. linerboards was fabricated with a 26-lb. European medium into A-flute combined board and boxes. The results obtained on boxes made with U.S. linerboard fabricated with 23.0-lb. and 26.0-lb. European semichemical medium and 26.0-lb. U.S. semichemical medium are tabulated in Tables XLV and XLVI, respectively, for 50 and 65% R.H. and illustrated in Fig. 44. It may be seen that on the basis of composite averages the boxes made with 23.0-lb. and 26.0-lb. European mediums give slightly higher top-load compression than boxes made with 26.0-lb. U.S. medium; however, the differences are not considered significant. The boxes made with 23.0-lb. European medium give lower end-load compression, and those with 26.0-lb. European medium give higher end-load

TABLE XLIII

EFFECT OF TYPE OF MEDIUM ON ROUGH HANDLING PER UNIT WEIGHT

(50% Relative *Humidity*)

		Corner Drops, Drops/100-lb. Combined Board Weight						Drum, Falls/100-lb. Combined Board Weight					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	26-lb. U.S. Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. U.S. Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. U.S. Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. U.S. Medium	23-lb. Eur. Medium	Diff.,[a] %
3, 4	26.0-lb. U.S.	8.9	6.8	-23.6	6.6	5.3	-19.7	82	69	-15.9	60	49	-18.3
2, 1	25.6-lb. E.G.	9.5	7.3	-23.2	6.5	5.7	-12.3	78	48	-38.5	60	54	-10.0
6, 5	25.6-lb. S.C.	6.7	5.4	-19.4	5.3	4.3	-18.9	77	72	- 6.5	54	28	-48.1
Composite		8.4	6.5	-22.6	6.1	5.1	-16.4	79	63	-20.3	58	44	-24.1
10, 9	33.0-lb. U.S.	8.9	8.0	-10.1	5.9	5.3	-10.2	96	101	+ 5.2	57	40	-29.8
7, 8	30.7-lb. E.G.	8.7	7.5	-13.8	6.5	6.6	+ 1.5	92	54	-41.3	59	43	-27.1
11, 12	30.7-lb. S.C.	9.8	10.2	+ 4.1	7.9	6.9	-12.7	110	84	-23.6	84	61	-27.4
Composite		9.1	8.6	- 5.5	6.8	6.3	- 7.4	99	80	-19.2	67	48	-28.4
15, 16	38.0-lb. U.S.	9.9	9.8	-14.1	8.5	7.3	-14.1	125	102	-18.4	74	65	-12.2
14, 13	35.8-lb. E.G.	9.1	7.8	-14.3	7.4	7.1	- 4.1	103	80	-22.3	67	62	- 7.5
18, 17	35.8-lb. S.C.	11.7	9.7	-17.1	9.8	8.1	-17.3	124	94	-24.2	102	69	-32.4
Composite		10.2	9.1	-10.8	8.6	7.5	-12.8	117	92	-21.4	81	65	-19.8
23, 24	42.0-lb. U.S.	10.2	8.3	-18.6	7.9	6.7	-15.2	111	87	-21.6	75	64	-14.7
19, 20	41.0-lb. E.G.	10.3	9.3	- 9.7	7.9	7.7	- 2.5	118	90	-23.7	79	45	-36.7
22, 21	41.0-lb. S.C.	10.2	8.4	-17.6	9.1	7.7	-15.4	114	97	-14.9	69	82	+18.8
Composite		10.2	8.7	-14.7	8.3	7.4	-10.8	114	91	-20.2	74	64	-13.5

[a] U.S. 26.0-lb. medium used as reference.

TABLE XLIV

EFFECT OF TYPE OF MEDIUM ON ROUGH HANDLING PER UNIT WEIGHT

(65% Relative Humidity)

		Corner Drops, Drops/100-lb Combined Board Weight						Drum, Falls/100-lb Combined Board Weight					
		A-Flute			B-Flute			A-Flute			B-Flute		
Run	Nominal Liner Weight	26-lb U S Medium	23-lb Eur Medium	Diff, % [a]	26-lb U S Medium	23-lb. Eur Medium	Diff, % [a]	26-lb U S. Medium	23-lb Eur Medium	Diff, % [a]	26-lb U S Medium	23-lb Eur Medium	Diff, % [a]
3, 4	26.0-lb U S	11.0	8.2	-25.5	8.8	7.3	-17.0	89	63	-29.2	53	54	+1.9
2, 1	25.6-lb E G	11.2	9.0	-19.6	9.6	8.0	-16.7	81	57	-29.6	57	59	+3.5
6, 5	25.6-lb S C	11.0	7.8	-29.1	7.4	7.6	+2.7	82	56	-31.7	52	37	-28.8
Composite		11.1	8.3	-25.2	8.6	7.6	-11.6	84	59	-29.8	54	50	-7.4
10, 9	33.0-lb U S	11.2	9.3	-17.0	8.1	8.1	0.0	85	95	+11.8	71	50	-29.6
7, 8	30.7-lb E G	10.8	9.4	-13.0	10.0	9.0	-10.0	84	73	-13.1	61	51	-16.4
11, 12	30.7-lb. S.C	13.1	13.6	+3.8	11.3	8.7	-23.0	93	98	+5.4	81	75	-7.4
Composite		11.7	10.8	-7.7	9.8	8.6	-12.2	87	89	+2.3	71	59	-16.9
15, 16	38.0-lb U S	10.8	9.6	-11.1	10.1	9.4	-6.9	119	97	-18.5	78	82	+5.1
14, 13	35.8-lb E G	11.6	11.0	-5.2	8.5	10.1	+18.8	85	90	+5.9	65	71	+9.2
18, 17	35.8-lb S C	16.8	11.6	-31.0	12.2	11.4	-6.6	135	109	-19.3	76	84	+10.5
Composite		13.1	10.7	-18.3	10.3	10.3	0.0	113	99	-12.4	73	79	+8.2
23, 24	42.0-lb U S	12.0	10.1	-15.8	9.3	9.6	+3.2	139	120	-13.7	81	80	-1.2
19, 20	41.0-lb E G	14.0	10.6	-24.3	11.0	9.8	-10.9	118	76	-35.6	87	76	-12.6
22, 21	41.0-lb S C	14.4	14.2	-1.4	10.7	12.0	+12.1	139	93	-33.1	82	81	-1.2
Composite		13.5	11.6	-14.1	10.3	10.5	+1.9	132	96	-27.3	83	79	-4.8

[a] U.S. 26.0-lb. medium used as reference.

TABLE XLV

COMPARATIVE BOX PERFORMANCE AT 50% R.H. FOR BOXES MADE WITH 23 AND 26-LB. EUROPEAN AND 26-LB. DOMESTIC MEDIUM

Runs	Liner Grade	26-lb. Domestic Medium	23-lb. European Medium	Diff., %a	26-lb. European Medium	Diff., %a
Top-Load Compression, lb.						
3,4,24D	US-26	530	565	+6.6	545	+2.8
10,9,24C	US-33	595	590	-0.8	655	+10.1
15,16,24B	US-38	635	660	+3.9	645	+1.6
23,24,24A	US-42	730	725	-0.7	730	0.0
Composite		622	635	+2.1	644	+3.5
End-Load Compression, lb.						
3,4,24D	US-26	270	255	-5.6	250	-7.4
10,9,24C	US-33	345	350	+1.4	370	+7.2
15,16,24B	US-38	400	400	0.0	390	-2.5
23,24,24A	US-42	455	440	-3.3	485	+6.6
Composite		368	361	-1.9	374	+1.6
Corner Drop, drops to failure						
3,4,24D	US-26	9.1	6.6	-27.5	6.6	-27.5
10,9,24C	US-33	10.1	8.7	-13.9	8.6	-14.9
15,16,24B	US-38	12.2	11.6	-4.9	10.0	-18.0
23,24,24A	US-42	13.3	10.4	-21.8	11.4	-14.3
Composite		11.2	9.3	-17.0	9.2	-17.9
Drum, falls to failure						
3,4,24D	US-26	84	67	-20.2	81	-3.6
10,9,24C	US-33	110	110	0.0	128	+16.3
15,16,24B	US-38	154	120	-22.1	94	-39.0
23,24,24A	US-42	144	110	-23.6	138	-4.2
Composite		123	102	-17.1	110	-10.6

[a] Based on 26-lb. domestic medium results as reference.

TABLE XLVI

COMPARATIVE BOX PERFORMANCE AT 65% R.H. FOR BOXES MADE WITH 23 AND 26-LB. EUROPEAN AND 26-LB. DOMESTIC MEDIUM

Runs	Liner Grade	26-lb. Domestic Medium	23-lb. European Medium	Diff., %[a]	26-lb. European Medium	Diff., %[a]
			Top-Load Compression, lb.			
3,4,24D	US-26	490	520	+6.1	495	+1.0
10,9,24C	US-33	560	540	-3.6	580	+3.6
15,16,24B	US-38	600	600	0.0	605	+0.8
23,24,24A	US-42	670	675	+0.7	645	-3.7
Composite		580	584	+0.7	581	+0.2
			End-Load Compression, lb.			
3,4,24D	US-26	235	225	-4.3	230	-2.1
10,9,24C	US-33	330	305	-7.6	325	-1.5
15,16,24B	US-38	360	345	-4.2	390	+8.3
23,24,24A	US-42	420	410	-2.4	420	0.0
Composite		336	321	-4.5	341	+1.5
			Corner Drop, drops to failure			
3,4,24D	US-26	11.4	8.1	-28.9	8.3	-27.2
10,9,24C	US-33	13.0	10.4	-20.0	11.9	-8.5
15,16,24B	US-38	13.6	11.7	-14.0	12.5	-8.1
23,24,24A	US-42	15.9	12.9	-18.9	13.8	-13.2
Composite		13.5	10.8	-20.0	11.6	-14.1
			Drum, falls to failure			
3,4,24D	US-26	92	62	-32.6	78	-15.2
10,9,24C	US-33	99	106	+7.1	99	0.0
15,16,24B	US-38	150	118	-21.3	114	-24.0
23,24,24A	US-42	185	153	-17.3	121	-34.6
Composite		132	110	-16.7	103	-22.0

[a]Based on 26-lb. domestic medium results as reference.

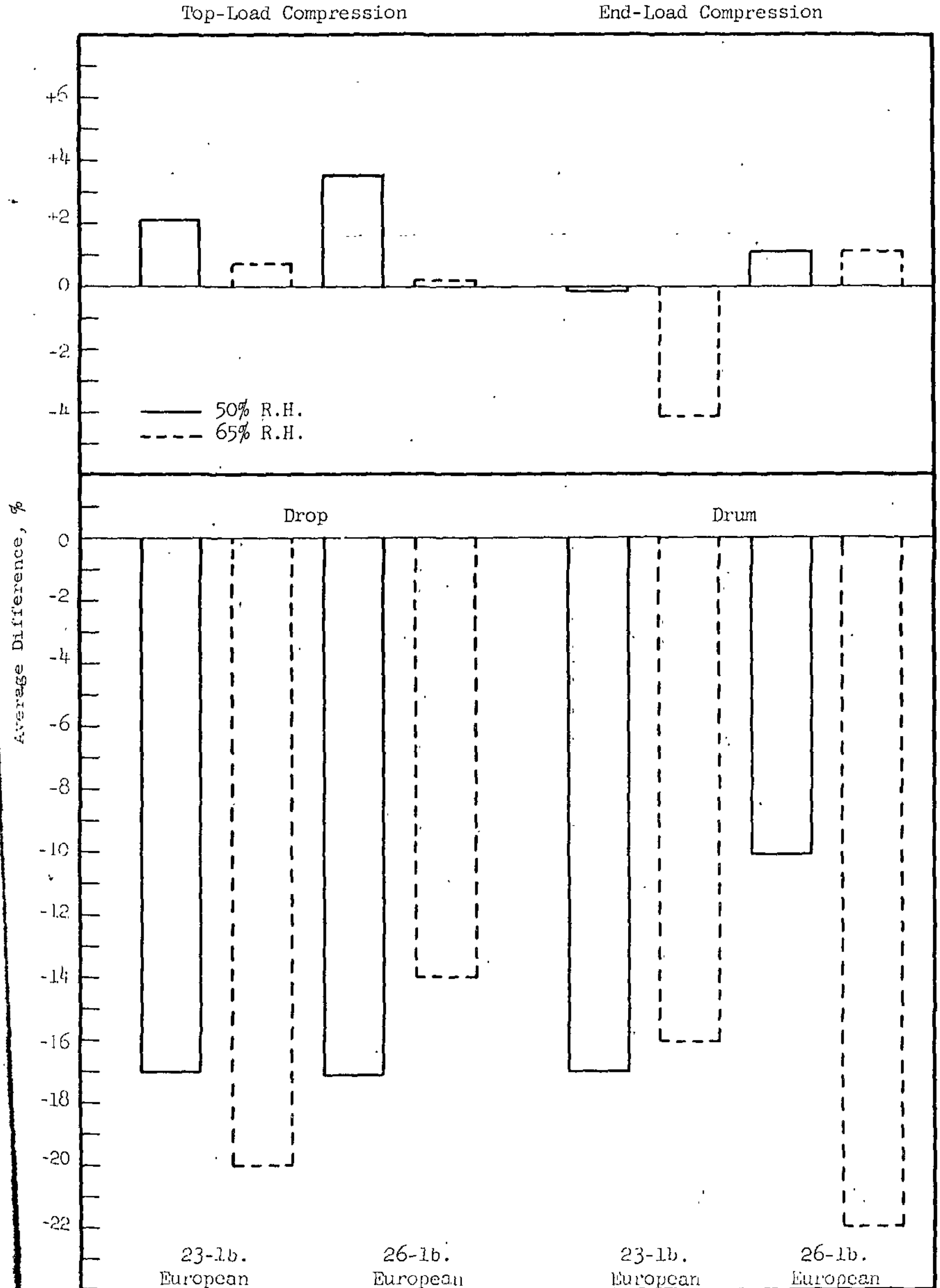


Figure 44. Comparison of the Effect of Medium (26-lb. U.S. as Reference vs. 23-lb. and 26-lb. European Mediums) on Average Difference

compression than boxes made with 26.0-lb. U.S. mediums; however, the differences are not believed to be significant. When rough handling is considered it may be seen that boxes made with European mediums give lower performance than boxes made with 26.0-lb. U.S. medium. There appears to be little if any difference between the rough handling performance of boxes made with 23.0-lb. and 26.0-lb. European mediums.

B. Comparison of the Physical Properties of Combined Boards Fabricated with U.S. and European Mediums

It may be recalled that each of the linerboards used in this study was fabricated with a 23-lb. European and a 26-lb. U.S. semichemical corrugating medium into A-flute and B-flute combined boards and boxes. In addition, the U.S. linerboards were also fabricated with a roll of 26-lb. European corrugating medium into A-flute combined board and boxes.

For the purpose of comparing the relative effects of 23-lb. European and 26-lb. U.S. mediums on physical properties of the combined boards, the combined board results presented in Tables XVI and XVII have been retabulated in Tables XLVII through LIX. A comparison of the effect of type of medium on combined board weight and bursting strength may be noted from the results tabulated in Tables XLVII and XLVIII, respectively, for 50 and 65% R.H. As would be expected, the combined board made with the 23.0-lb. European medium exhibits 3-5% lower weight. The composite average difference in basis weight of combined board made with 26.0-lb. U.S. medium and 23.0-lb. European medium is as follows and is graphically illustrated in Fig. 45.

TABLE XLVII

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD WEIGHT AND BURSTING STRENGTH
(50% Relative humidity)

Run	Nominal Weight Linerboard	Basis Weight, lb./M sq. ft.						Bursting Strength, p.s.i.g.					
		26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	102	97	-4.9	94	91 89	-3.2	148	149	+0.7	130	135	+3.8
2,1	25.6-lb. EG	99	94	-5.1	94	89	-5.3	204	204	0.0	168	182	+8.3
6,5	25.6-lb. SC	97	93	-4.1	94	89	-5.3	232	236	+1.7	172	186	+8.1
Composite		99.3	94.7	-4.6	94	89.7	-4.6	195	196	+0.5	157	168	+7.0
10,9	33.0-lb. US	114	109	-4.4	111	106	-4.5	218	224	+2.8	184	206	+12.0
7,8	30.7-lb. EG	108	104	-3.7	105	100	-4.8	241	264	+9.5	238	262	+10.1
11,12	30.7-lb. SC	107	103	-3.7	104	98	-5.8	232	240	+3.4	214	232	+8.4
Composite		109.7	105.3	-4.0	106.7	101.3	-5.1	230	243	+5.7	212	233	+9.9
15,16	38.0-lb. US	123	118	-4.1	119	113	-5.0	218	222	+1.8	190	219	+15.3
14,13	35.7-lb. EG	119	114	-4.2	114	109	-4.4	298	298	0.0	262	282	+7.6
18,17	35.7-lb. SC	118	113	-4.2	114	107	-6.1	279	280	+0.4	262	272	+3.8
Composite		120.0	115.0	-4.2	115.7	109.7	-5.2	265	267	+0.8	238	258	+8.4
23,24	42.0-lb. US	130	126	-3.1	126	120	-4.8	240	287	+19.6	226	235	+4.0
19,20	41.0-lb. EG	128	123	-3.9	122	119	-2.5	324	322	-0.6	258	316	+22.5
22,21	41.0-lb. SC	124	120	-3.2	118	116	-1.7	297	338	+13.8	292	310	+6.2
Composite		127.3	123.0	-3.4	122.0	118.3	-3.0	287	316	+10.1	259	287	+10.8

[a]Combined board made with 26-lb. US medium used as reference.

TABLE XLVIII

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD WEIGHT AND BURSTING STRENGTH
(65% Relative humidity)

		Basis Weight, lb./M sq. ft.						Bursting Strength, p.s.i.g.					
Run	Nominal Weight Linerboard	26-lb. US Medium	23-lb. Eur Medium	Diff.,[a] %	26-lb US Medium	23-lb. Eur Medium	Diff.,[a] %	26-lb US Medium	23-lb Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb Eur Medium	Diff.,[a] %
			A-Flute			B-Flute			A-Flute			B-Flute	
3,4	26.0-lb. US	104	99	-4.8	98	94	-4.2	164	170	+3.7	132	139	+5.3
2,1	25.6-lb. EG	101	96	-5.0	96	91	-5.2	228	202	-11.4	184	237	+28.8
6,5	25.6-lb. SC	99	95	-4.0	96	90	-6.2	258	251	-2.7	236	251	+6.4
Composite		101.3	96.7	-4.5	96.7	91.7	-5.2	217	208	-4.1	184	209	+13.6
10, 9	33.0-lb US	116	112	-3.4	113	110	-2.7	239	250	+4.6	208	229	+10.1
7,8	30.7-lb EG	111	107	-3.6	106	102	-3.8	290	310	+6.9	247	287	+16.2
11,12	30.7-lb. SC	110	104	-5.5	106	101	-4.7	246	258	+4.9	238	227	-4.6
Composite		112.3	107.7	-4.1	108.3	104.3	-3.7	258	273	+5.8	231	248	+7.4
15,16	38.0-lb. US	126	122	-3.2	121	115	-5.0	242	242	0.0	248	251	+1.2
14,13	35.8-lb. EG	123	117	-4.9	116	112	-3.4	315	322	+2.2	295	326	+10.5
18,17	35.8-lb. SC	120	116	-3.3	115	109	-5.2	320	336	+5.0	290	320	+10.3
Composite		123	118.3	-3.8	117.3	112	-4.5	292	300	+2.7	278	299	+7.6
23,24	42.0-lb. US	133	128	-3.8	128	122	-4.7	260	284	+9.2	254	278	+9.4
19,20	41.0-lb. EG	131	127	-3.1	126	121	-4.0	346	347	+0.3	323	342	+5.9
22,21	41.0-lb. SC	129	122	-5.4	123	115	-6.5	348	376	+8.0	334	344	+3.0
Composite		131	125.7	-4.0	125.7	119.3	-5.1	318	336	+5.7	304	321	+5.7

[a]Combined board made with 26-lb. US medium used as reference.

TABLE XLIX

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD FLAT CRUSH AND PUNCTURE STRENGTH
(50% Relative humidity)

		Flat Crush, p.s.i.						Puncture, unit					
Run	Nominal Weight Linerboard	26-lb. US Medium	23-lb. Eur Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb. Eur. Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	36.2	30.8	-14.9	54.4	53.2	-2.2	185	171	-7.6	162	154	-4.9
2,1	25.6-lb. EG	33.8	30.6	-9.5	51.4	45.2	-12.1	180	160	-11.1	160	144	-10.0
6,5	25.6-lb. SC	36.4	30.3	-16.8	54.9	47.2	-14.0	166	156	-6.0	162	146	-9.9
Composite		35.5	30.6	-13.8	53.6	48.5	-9.5	177	162	-8.5	161	148	-8.1
10,9	33.0-lb US	35.4	31.6	-10.7	56.1	47.2	-15.9	200	188	-6.0	192	173	-9.9
7,8	30.7-lb. EG	37.1	32.5	-12.4	53.4	47.8	-10.5	190	179	-5.8	180	164	-8.9
11,12	30.7-lb. SC	36.0	33.3	-7.5	57.3	44.1	-23.0	192	181	-5.7	175	162	-7.4
Composite		36.2	32.5	-10.2	55.6	46.4	-16.5	194	183	-5.7	182	166	-8.8
15,16	38.0-lb. US	36.0	32.3	-10.3	51.3	46.0	-10.3	218	210	-3.7	197	184	-6.6
14,13	35.9-lb. EG	36.7	32.4	-11.7	51.0	47.3	-7.3	206	194	-5.8	182	178	-2.2
18,17	35.2-lb SC	34.7	32.3	-6.9	52.4	44.9	-14.3	216	200	-7.4	193	173	-10.4
Composite		35.8	32.3	-9.8	51.6	46.1	-10.7	213	201	-5.6	191	178	-6.8
23,24	42.0-lb. US	35.4	34.8	-1.7	52.5	46.8	-10.9	232	220	-5.2	208	196	-5.8
19,20	41.0-lb. EG	35.4	34.7	-2.0	52.2	42.5	-18.6	233	208	-10.7	204	195	-4.4
22,21	41.0-lb SC	37.6	34.0	-9.6	49.9	46.2	-7.4	234	214	-8.5	200	186	-7.0
Composite		36.1	34.5	-4.4	51.5	45.2	-12.2	233	214	-8.2	204	192	-5.9

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE L

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD FLAT CRUSH AND PUNCTURE STRENGTH
(65% Relative humidity)

Run	Nominal Weight	Flat Crush, p.s.i. 26-lb US Medium	23-lb Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb. Eur. Medium	Diff.,[a] %	Puncture, unit 26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb Eur Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	33.5	30.0	-10.4	56.1	52.2	-7.0	182	164	-9.9	175	168	-4.0
2,1	25.6-lb EG	32.6	27.6	-15.3	55.8	45.9	-17.7	176	160	-9.1	170	150	-11.8
6,5	25.6-lb. SC	33.5	29.6	-11.6	55.9	49.0	-12.3	170	158	-7.1	170	154	-9.4
Composite		33.2	29.1	-12.3	55.9	49.0	-12.3	176	161	-8.5	172	157	-8.7
10,9	33.0-lb US	32.6	28.7	-12.0	53.4	48.5	-9.2	196	189	-3.6	208	183	-12.0
7,8	30.7-lb EG	31.6	30.1	-4.7	55.2	49.6	-10.1	195	183	-6.2	190	176	-7.4
11,12	30.7-lb. SC	31.5	30.5	-3.2	53.6	51.9	-3.2	191	176	-7.9	195	182	-6.7
Composite		32.9	29.8	-9.4	54.1	50.0	-7.6	194	183	-5.6	198	180	-9.1
15,16	38.0-lb. US	32.6	29.7	-8.9	55.6	53.4	-4.5	216	214	-0.9	217	204	-6.0
14,13	35.8-lb. EG	30.3	30.9	+2.0	54.3	48.7	-10.3	214	200	-6.5	203	192	-5.4
18,17	35.8-lb. SC	33.3	30.8	-7.5	51.4	53.5	+4.1	216	198	-8.3	206	194	-5.8
Composite		32.1	30.5	-5.0	53.9	51.9	-3.7	215	204	-5.1	209	197	-5.7
23,24	42.0-lb. US	31.2	30.4	-2.6	56.2	51.3	-8.7	238	216	-9.2	230	211	-8.3
19,20	41.0-lb. EG	32.0	30.9	-3.4	55.4	51.9	-6.3	230	226	-1.7	228	216	-5.3
22,21	41.0-lb. SC	32.9	31.8	-3.3	52.9	52.7	-0.4	226	209	-7.5	217	204	-6.0
Composite		32.0	31.0	-3.1	54.8	52.0	-5.1	231	217	-6.1	225	210	-6.7

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE LI

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD TORSION TEAR STRENGTH
(50% Relative humidity)

		Average Torsion Tear, in.-oz.						Scoreline Torsion Tear, in.-oz					
Run	Nominal Weight Linerboard	26-lb. US Medium	23-lb. Eur Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb Eur Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	215	186	-26.0	185	159	+0.5	202	162	-19.8	177	152	-14.1
2,1	25.6-lb. EG	196	168	-26.0	176	145	-17.6	186	151	-18.8	168	135	-19.6
6,5	25.6-lb. SC	182	176	-3.3	176	150	-14.8	172	154	-10.5	156	141	-9.6
Composite		198	176	-11.1	179	151	-15.6	187	156	-16.6	167	143	-14.4
10,9	33.0-lb. US	244	214	-12.3	224	190	-15.2	204	180	-11.8	208	181	-13.0
7,8	30.7-lb. EG	218	196	-10.1	196	178	-9.2	193	172	-10.9	188	163	-13.3
11,12	30.7-lb. SC	212	196	-7.6	195	167	-9.2	199	180	-9.5	203	168	-17.2
Composite		225	202	-10.2	205	178	-13.2	199	177	-11.5	200	171	-14.5
15,16	38.0-lb US	266	246	-7.5	232	204	-12.1	227	203	-10.6	216	194	-10.2
14,13	35.8-lb. EG	242	211	-12.8	217	191	-12.0	218	181	-17.0	195	174	-10.8
18,17	35.8-lb. SC	227	218	-4.0	230	198	-13.9	201	201	0.0	226	188	-16.8
Composite		245	225	-8.2	226	198	-12.4	215	195	-9.3	212	185	-12.7
23,24	42.0-lb. US	280	255	-8.9	258	224	-13.2	230	204	-11.3	236	200	-15.3
19,20	41.0-lb. EG	256	238	-7.0	241	214	-11.2	214	204	-4.7	224	204	-8.9
22,21	41.0-lb SC	242	216	-10.7	222	204	-8.1	204	185	-9.3	206	191	-7.3
Composite		259	236	-8.9	240	214	-10.8	216	198	-8.3	222	198	-10.8

[a] Combined board made with 26.0-lb. US medium used as reference.

TABLE LII

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD TORSION TEAR STRENGTH
(65% Relative humidity)

Run	Nominal Weight	Average Torsion Tear, in.-oz.						Scoreline Torsion Tear, in -oz					
		26-lb US Medium	23-lb Eur Medium	Diff., [a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff., [a] %	26-lb US Medium	23-lb. Eur Medium	Diff., [a] %	26-lb US Medium	23-lb Eur Medium	Diff., [a] %
			A-Flute			B-Flute			A-Flute			B-Flute	
3,4	26.0-lb US	236	200	-15.3	200	182	-9.0	223	187	-16.2	190	176	-7.4
2,1	25.6-lb. EG	223	178	-20.2	192	174	-9.4	203	164	-19.2	192	163	-15.1
6,5	25.6-lb. SC	220	202	-8.2	194	168	-14.4	194	180	-7.2	178	158	-11.2
Composite		226	193	-14.6	195	175	-10.3	207	177	-14.5	187	165	-11.2
10,9	33.0-lb US	264	246	-6.9	254	226	-11.0	234	212	-9.4	244	207	-15.2
7,8	30.7-lb. EG	241	216	-10.4	230	202	-12.2	222	193	-13.1	225	192	-14.7
11,12	30.7-lb. SC	238	206	-13.4	222	196	-11.7	223	201	-9.9	223	196	-12.1
Composite		248	223	-10.1	235	208	-11.5	226	202	-10.6	231	198	-14.3
15,16	38.0-lb. US	298	274	-8.1	266	236	-11.3	260	225	-13.5	242	205	-15.3
14,13	35.8-lb. EG	271	230	-15.1	232	206	-11.2	248	195	-21.4	226	202	-10.6
18,17	35.8-lb. SC	268	255	-4.9	246	228	-7.3	247	229	-7.3	251	217	-13.5
Composite		279	253	-9.3	248	223	-10.1	252	216	-13.7	240	208	-13.3
23,24	42.0-lb. US	296	282	-4.7	285	238	-16.5	255	235	-7.8	265	222	-16.2
19,20	41.0-lb. EG	280	272	-2.9	253	240	-5.1	251	238	-5.2	241	207	-14.1
22,21	41.0-lb. SC	272	246	-9.6	244	216	-11.5	239	207	-13.4	241	212	-12.0
Composite		283	267	-5.7	261	231	-11.5	248	227	-8.5	249	214	-14.1

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE LIII

EFFECT OF TYPE OF MEDIUM OF COMBINED BOARD ON CALIPER AND FLEXURAL STIFFNESS GEOMETRIC MEAN
(50% Relative humidity)

Run	Nominal Weight Linerboard	Flexural Stiffness Mean $\sqrt{D_x D_y}$, lb.-in.						Caliper, pt.					
		26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	25.0-lb. US	82.6	90.8	+9.9	29.1	29.8	+2.4	191	193	+1.0	113	112	-0.9
2,1	25.6-lb. EG	87.1	93.5	+7.3	33.2	36.1	+8.7	188	188	0.0	111	109	-1.8
6,5	25.6-lb. SC	92.6	93.0	+0.4	32.1	31.1	-3.1	189	190	+0.5	111	109	-1.8
Composite		87.4	92.4	+5.7	31.5	32.3	+2.5	189	190	+0.5	112	110	-1.8
10,9	33.0-lb. US	125.1	131.4	+5.0	39.5	40.3	+2.0	193	192	-0.5	115	112	-2.6
7,8	30.7-lb. EG	134.1	144.2	+7.5	46.0	42.6	-7.4	188	190	+1.1	112	109	-2.7
11,12	30.7-lb. SC	117.5	128.1	+9.0	38.2	40.4	+5.8	190	190	0.0	114	111	-2.6
Composite		125.6	134.6	+7.2	41.2	41.1	-0.2	190	191	+0.5	114	111	-2.6
15,16	38.0-lb. US	118.1	122.6	+3.8	40.7	39.6	-2.7	200	195	-2.5	117	114	-2.6
14,13	35.8-lb. EG	168.6	169.3	+0.4	53.8	52.0	-3.3	196	194	-1.0	114	113	-0.9
18,17	35.8-lb. SC	132.5	147.4	+11.2	43.2	45.3	+4.9	197	194	-1.5	114	113	-0.9
Composite		139.7	146.4	+4.8	45.9	45.6	+6.5	198	194	-1.5	115	113	-1.7
23,24	42.0-lb. US	142.2	140.1	-1.5	42.3	42.6	+0.7	199	194	-2.5	118	115	-2.5
19,20	41.0-lb. EG	181.9	203.8	+12.0	57.8	58.0	+0.3	197	196	-0.5	117	113	-3.4
22,21	41.0-lb. SC	164.6	166.0	+0.9	48.0	48.0	0.0	200	196	-2.0	118	116	-1.7
Composite		162.9	170.0	+4.4	49.4	49.5	+0.2	199	195	-2.0	118	115	-2.5

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE LIV

EFFECT OF TYPE OF MEDIUM OF COMBINED BOARD ON CALIPER AND FLEXURAL STIFFNESS GEOMETRIC MEAN
(65% Relative humidity)

		Flexural Stiffness Mean $\sqrt{D_x D_y}$, lb.-in.						Caliper, pt.					
Run	Nominal Weight Linerboard	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	81.7	84.4	+3.3	26.2	26.8	+2.3	196	192	-2.0	114	114	0.0
2,1	25.6-lb. EG	93.5	93.9	+0.4	30.4	31.8	+2.6	188	190	+1.1	111	110	-0.9
6,5	25.6-lb. SC	85.1	86.7	+1.9	29.3	28.5	-2.7	190	185	-2.6	111	110	-0.9
Composite		86.8	88.3	+1.7	28.6	28.8	+0.7	191	189	-1.0	112	111	-0.9
10,9	33.0-lb. US	111.4	110.7	-0.6	35.5	36.0	+1.4	194	193	-0.5	115	113	-1.7
7,8	30.7-lb. EG	119.1	128.4	+7.8	38.3	39.0	+1.8	191	190	-0.5	113	112	-0.9
11,12	30.7-lb. SC	111.9	107.5	-3.9	34.7	34.7	0.0	195	194	-0.5	114	113	-0.9
Composite		114.1	115.5	+1.2	36.2	36.6	+1.1	193	192	-0.5	114	113	-0.9
15,16	38.0-lb. US	109.6	110.3	+0.6	37.2	37.4	+-.5	198	194	-2.0	118	115	-2.5
14,13	35.8-lb. EG	149.3	147.6	-1.1	49.8	48.9	-1.8	196	195	-0.5	116	113	-2.6
18,17	35.8-lb. SC	116.8	125.6	+7.5	39.2	41.3	+5.4	195	195	0.0	115	113	-1.7
Composite		125.2	127.8	+2.1	42.1	42.5	+1.0	196	195	-0.5	116	114	-1.7
23,24	42.0-lb. US	122.3	123.8	+1.2	41.0	39.6	-3.4	199	198	-0.5	118	116	-1.7
19,20	41.0-lb. EG	163.7	160.5	-2.0	53.9	56.4	+4.6	197	196	-0.5	117	115	-1.7
22,21	41.0-lb. SC	137.8	135.4	-1.7	48.1	44.1	-8.3	198	196	-1.0	118	116	-1.7
Composite		141.3	139.9	-1.0	47.7	46.7	-2.1	198	197	-0.5	118	116	-1.7

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE LV

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD EDGEWISE COMPRESSION
(50% Relative humidity)

Run	Nominal Weight Linerboard	Machine-Direction Edgewise Compression, lb./in.						Cross-Direction Edgewise Compression, lb./in.					
		26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb. US	12.8	9.7	-24.2	19.4	16.7	-13.9	37.8	39.8	+5.3	38.7	38.3	-1.0
2,1	25.6-lb. EG	9.0	8.3	-7.8	18.0	17.4	-3.3	35.3	38.8	+9.9	36.0	39.9	+10.8
6,5	25.6-lb. SC	11.1	9.8	-11.7	18.9	19.2	+1.6	32.8	36.6	+11.6	37.8	40.4	+6.9
Composite		11.0	9.3	-15.4	18.8	17.8	-5.3	35.3	38.4	+8.8	37.5	39.5	+5.3
10,9	33.0-lb. US	14.9	13.4	-10.1	29.8	28.3	-5.0	41.7	44.8	+7.4	48.0	49.9	+4.0
7,8	30.7-lb. EG	13.6	13.8	+1.5	24.8	25.2	+1.6	38.3	41.4	+8.1	45.8	46.6	+1.7
11,12	30.7-lb. SC	16.5	15.7	-4.8	27.6	23.0	-16.7	38.7	44.0	+13.7	44.0	43.9	-0.2
Composite		15.0	14.3	-4.7	27.4	25.5	-6.9	39.6	43.4	+9.6	45.9	46.8	+2.0
15,16	38.0-lb. US	16.7	18.5	+10.8	31.5	30.5	-3.2	43.9	45.8	+4.3	48.3	48.8	+1.0
14,13	35.8-lb. EG	18.1	17.1	-5.5	31.8	30.4	-4.4	43.2	46.5	+7.6	50.9	51.0	+0.2
18,17	35.8-lb. SC	17.2	16.0	-7.0	28.6	28.8	+0.7	45.2	47.4	+4.9	47.0	51.7	+10.0
Composite		17.3	17.2	-0.6	30.6	29.9	-2.2	44.1	46.6	+5.7	48.7	50.5	+3.7
23,24	42.0-lb. US	21.2	21.2	0.0	37.0	31.9	-13.8	47.4	50.3	+6.1	49.8	52.6	+5.6
19,20	41.0-lb. EG	20.1	22.2	+10.4	41.0	38.0	-7.3	50.1	52.2	+4.2	52.4	54.0	+3.1
22,21	41.0-lb. SC	23.4	25.5	+9.0	35.2	35.4	+0.6	47.0	53.6	+14.0	46.8	52.3	+11.8
Composite		21.6	23.0	+6.5	37.7	35.1	-6.9	48.2	52.0	+7.9	49.7	53.0	+6.6

[a]Combined board made with 26-lb. US medium used as reference.

TABLE LVI

EFFECT OF TYPE OF MEDIUM ON COMBINED BOARD EDGEWISE COMPRESSION
(65% Relative humidity)

Run	Nominal Weight Linerboard	Machine-Direction Edgewise Compression, lb./in.						Cross-Direction Edgewise Compression, lb./in					
		A-Flute			B-Flute			A-Flute			B-Flute		
		26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb US Medium	23-lb Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb Eur Medium	Diff.,[a] %
3,4	26.0-lb US	12.2	11.8	-3.3	20.7	20.1	-2.9	36.5	38.9	+6.6	37.7	38.3	+1.6
2,1	25.6-lb. EG	11.0	10.2	-7.3	18.5	17.6	-4.9	34.6	37.3	+7.8	34.6	37.0	+6.9
6,5	25.6-lb. SC	12.3	10.9	-11.4	19.3	19.6	+1.6	33.7	35.8	+6.2	36.9	37.9	+2.7
Composite		11.8	11.0	-6.8	19.5	19.1	-2.1	34.9	37.3	+6.9	36.4	37.7	+3.6
10,9	33.0-lb. US	15.6	14.7	-7.0	29.0	27.1	-6.6	41.4	43.6	+5.3	43.4	45.1	+3.9
7,8	30.7-lb EG	14.2	14.0	-1.4	25.8	22.8	-11.6	40.5	41.4	+2.2	44.0	43.7	-0.7
11,12	30.7-lb. SC	17.2	16.5	-4.1	26.0	23.6	-9.2	38.8	42.6	+9.8	41.8	45.0	+7.7
Composite		15.7	15.1	-3.8	26.9	24.5	-8.9	40.2	42.5	+5.7	43.1	44.6	+8.1
15,16	38.0-lb. US	20.7	19.3	-6.8	32.2	30.7	-4.7	42.7	45.6	+6.8	45.1	44.9	-0.4
14,13	35.8-lb. EG	19.8	18.0	-9.1	35.0	32.4	-7.4	43.7	46.4	+6.2	46.3	50.8	+9.7
18,17	35.8-lb. SC	19.4	17.4	-10.3	30.6	28.5	-7.2	42.7	45.9	+7.5	44.8	48.1	+7.4
Composite		20.0	18.2	-9.0	32.6	30.5	-6.4	43.0	46.0	+7.0	45.4	47.9	+5.5
23,24	42.0-lb. US	23.7	20.9	-11.8	36.9	35.3	-4.3	46.9	50.0	+6.6	47.1	49.8	+5.7
19,20	41.0-lb EG	26.5	24.5	-7.5	40.0	38.9	-2.8	48.6	50.9	+4.7	48.8	50.3	+3.1
22,21	41.0-lb SC	24.0	25.6	+6.7	40.1	38.0	-5.2	47.2	50.5	+7.0	45.3	48.9	+7.9
Composite		24.7	23.7	-4.0	39.0	37.4	-4.1	47.6	50.5	+6.1	47.1	49.7	+5.5

[a] Combined board made with 26-lb. US medium used as reference.

TABLE LVII

EFFECT OF TYPE OF MEDIUM ON PIN ADHESION

Pin Adhesion, lb./4 sq. in.

Run	Nominal Weight Linerboard	(50% Relative Humidity) 26-lb. US Medium	23-lb Eur Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	(65% Relative Humidity) 26-lb. US Medium	23-lb. Eur. Medium	Diff.,[a] %	26-lb. US Medium	23-lb. Eur Medium	Diff.,[a] %
		A-Flute			B-Flute			A-Flute			B-Flute		
3,4	26.0-lb US	42	38	-9.5	76	76	0.0	36	30	-16.7	79	70	-11.4
2,1	25.6-lb. EG	35	33	-5.7	62	56	-9.7	35	31	-11.4	70	58	-17.1
6,5	25.6-lb SC	32	28	-12.5	72	64	11.1	30	31	+3.3	62	50	-12.9
Composite		36	33	-9.1	70	65	-7.1	34	31	-8.8	70	59	-15.7
10,9	33.0-lb US	38	34	-10.5	86	70	-18.6	27	31	+14.8	75	77	+2.7
7,8	30.7-lb EG	30	28	-6.7	65	53	-18.5	30	25	-16.7	69	57	-17.4
11,12	30.7-lb. SC	35	32	-8.6	65	84	+29.2	32	30	-6.3	68	60	-11.8
Composite		34	31	-8.8	72	69	-4.2	30	29	-3.3	71	65	-8.5
15,16	38.0-lb. US	40	37	-7.5	52	62	+19.2	34	35	+2.9	56	58	+3.6
14,13	35.8-lb EG	36	32	-11.1	48	50	+4.2	31	30	-3.2	46	68	+47.8
18,17	35.8-lb. SC	35	34	-2.9	60	52	-13.3	31	31	0.0	60	50	-16.7
Composite		37	34	-8.1	53	55	+3.8	32	32	0.0	54	59	+9.3
23,24	42.0-lb. US	44	44	0.0	61	62	+1.6	38	37	-2.6	70	57	-18.6
19,20	41.0-lb EG	44	42	-4.5	59	56	-5.1	38	36	-5.3	46	52	+13.0
22,21	41.0-lb SC	44	44	0.0	63	60	-4.8	38	38	0.0	55	63	+14.5
Composite		44	43	-2.3	61	59	-3.3	38	37	-2.6	57	57	0.0

[a]Combined board made with 26.0-lb. US medium used as reference.

TABLE LVIII

COMPARATIVE COMBINED BOARD PERFORMANCE AT 50% R.H. FOR A-FLUTE COMBINED BOARDS MADE WITH 23 AND 26-LB. EUROPEAN MEDIUM AND 26-LB. US MEDIUM

Runs	US Linerboard Grade Weight	26-lb. Domestic Medium	23-lb. European Medium	Diff., %[a]	26-lb. European Medium	Diff., %[a]
		Basis Weight, lb./M sq. ft.				
3, 4, 24D	26	102	97	- 4.9	101	- 1.0
10, 9, 24C	33	114	109	- 4.4	114	0.0
15, 16, 24B	38	123	118	- 4.1	124	+ 0.8
23, 24, 24A	42	130	126	- 3.1	129	- 0.8
Composite		117	112	- 4.3	117	0.0
		Bursting Strength, p.s.i.				
3, 4, 24D	26	148	149	+ 0.7	146	- 1.4
10, 9, 24C	33	218	224	+ 2.8	203	- 6.9
15, 16, 24B	38	218	222	+ 1.8	224	+ 2.8
23, 24, 24A	42	240	287	+19.6	252	+ 5.0
Composite		206	220	+ 6.8	206	0.0
		Puncture, unit				
3, 4, 24D	26	185	171	- 7.6	186	+ 0.5
10, 9, 24C	33	200	188	- 6.0	206	+ 3.0
15, 16, 24B	38	218	210	- 3.7	231	+ 6.0
23, 24, 24A	42	232	220	- 5.2	232	0.0
Composite		209	197	- 5.7	214	+ 2.4
		Flat Crush, p.s.i.				
3, 4, 24D	26	36.2	30.8	-14.9	36.6	+ 1.1
10, 9, 24C	33	35.4	31.6	-10.7	36.7	+ 3.7
15, 16, 24B	38	36.0	32.3	-10.3	34.5	- 4.2
23, 24, 24A	42	35.4	34.8	- 1.7	37.2	+ 5.1
Composite		35.8	32.4	- 9.5	36.2	+ 1.1
		Flexural Stiffness $(\sqrt{D_x D_y})$, lb. sq. in./in.				
3, 4, 24D	26	82.6	90.8	+ 9.9	99.3	+20.2
10, 9, 24C	33	125.1	131.4	+ 5.0	138.2	+10.5
15, 16, 24B	38	118.1	122.6	+ 3.8	126.6	+ 7.2
23, 24, 24A	42	142.2	140.1	- 1.5	143.5	+ 0.9
Composite		117.0	121.2	+ 3.6	126.9	+ 8.5
		Edgewise Compression, lb./in. (in)				
3, 4, 24D	26	12.8	9.7	-24.2	12.7	- 0.8
10, 9, 24C	33	14.9	13.4	-10.1	16.2	+ 8.7
15, 16, 24B	38	16.7	18.5	+10.8	20.7	+24.0
23, 24, 24A	42	21.2	21.2	0.0	24.2	+14.2
Composite		16.4	15.7	- 4.3	18.4	+12.2

TABLE LVIII (Continued)

COMPARATIVE COMBINED BOARD PERFORMANCE AT 50% R.H. FOR A-FLUTE COMBINED BOARDS MADE WITH 23 AND 26-LB. EUROPEAN MEDIUM AND 26-LB. US MEDIUM

Runs	US Linerboard Grade Weight	26-lb. Domestic Medium	23-lb. European Medium	Diff., %[a]	26-lb. European Medium	Diff., %[a]
		Edgewise Compression, lb./in. (cross)				
·, 4, 24D	26	37.8	39.8	+ 5.3	39.8	+ 5.3
·0, 9, 24C	33	41.7	44.8	+ 7.4	46.6	+11.8
·5, 16, 24B	38	43.9	45.8	+ 4.3	48.1	+ 9.6
·3, 24, 24A	42	47.4	50.3	+ 6.1	50.3	+ 6.1
·omposite		42.7	45.2	+ 5.9	46.2	+ 8.2
		Torsion Tear, in.-oz. (av. in and cross)				
· 4, 24D	26	215	186	-13.5	202	- 6.0
·, 9, 24C	33	244	214	-12.3	232	- 4.9
·, 16, 24B	38	266	246	- 7.5	256	- 3.8
·, 24, 24A	42	280	255	- 8.9	260	- 7.1
·mposite		251	225	-10.4	238	- 5.2
		Torsion Tear, in.-oz. flap score				
4, 24D	26	202	162	-19.8	176	-12.9
· 9, 24C	33	204	180	-11.8	193	- 5.4
· 16, 24B	38	227	203	-10.6	210	- 7.5
24, 24A	42	230	204	-11.3	208	- 9.6
·posite		216	187	-13.4	197	- 8.8
		Caliper, pt.				
·, 24D	26	191	193	+ 1.0	197	+ 3.1
9, 24C	33	193	192	- 0.5	197	+ 2.1
16, 24B	38	200	195	- 2.5	199	- 0.5
24, 24A	42	199	194	- 2.5	200	+ 0.5
·osite		196	194	- 1.0	198	+ 1.0
		Pin Adhesion, lb./4 sq. in.				
· 24D	26	42	38	- 9.5	42	0.0
·, 24C	33	38	34	-10.5	35	- 7.9
·6, 24B	38	40	37	- 7.5	39	- 7.5
·4, 24A	42	44	44	0.0	42	0.0
·site		41	38	- 7.3	40	- 2.5

·ed on 26-lb. domestic medium results as reference.

TABLE LIX

COMPARATIVE COMBINED BOARD PERFORMANCE AT 65% R.H. FOR A-FLUTE COMBINED BOARDS MADE WITH 23- AND 26-LB. EUROPEAN MEDIUM AND 26-LB. DOMESTIC MEDIUM

Runs	US Linerboard Grade Weight	26-lb. Domestic Medium	23-lb. European Medium	Diff., %[a]	26-lb. European Medium	Diff., %[a]
		Basis Weight, lb./M sq. ft.				
3,4,24D	26	104	99	- 4.8	103	- 1.0
10,9,24C	33	116	112	- 3.4	117	+ 0.9
15,16,24B	38	126	122	- 3.2	127	+ 0.8
23,24,24A	42	133	128	- 3.8	132	- 0.8
Composite		120	115	- 4.2	120	0.0
		Bursting Strength, p.s.i.g.				
3,4,24D	26	164	170	+ 3.7	156	- 4.9
10,9,24C	33	239	250	+ 4.6	222	- 7.1
15,16,24B	38	242	242	0.0	248	+ 2.5
23,24,24A	42	260	284	+ 9.2	285	+ 9.6
Composite		226	236	+ 4.4	228	+ 0.9
		Puncture, unit				
3,4,24D	26	182	164	- 9.9	179	- 1.6
10,9,24C	33	196	189	- 3.6	206	+ 5.1
15,16,24B	38	216	214	- 0.9	229	+ 6.0
23,24,24A	42	238	216	- 9.2	228	- 4.2
Composite		208	196	- 5.8	210	+ 1.0
		Flat Crush, p.s.i.				
3,4,24D	26	33.5	30.0	-10.4	36.5	+ 9.0
10,9,24C	33	32.6	28.7	-12.0	35.5	+ 8.9
15,16,24B	38	32.6	29.7	- 8.9	33.9	+ 4.0
23,24,24A	42	31.2	30.4	- 2.6	34.1	+ 9.3
Composite		32.5	29.7	- 8.6	35.0	+ 7.7
		Flexural Stiffness ($\sqrt{D_x D_y}$), lb. sq. in./in.				
3,4,24D	26	81.7	84.4	+ 3.3	85.0	+ 4.0
10,9,24C	33	111.4	110.7	- 0.6	111.1	- 0.3
15,16,24B	38	109.6	110.3	+ 0.6	108.5	- 1.0
23,24,24A	42	122.3	123.8	+ 1.2	122.0	- 0.2
Composite		106.2	107.3	+ 1.0	106.6	+ 0.4
		Edgewise Compression, lb./in. (in)				
3,4,24D	26	12.2	11.8	- 3.3	13.1	+ 7.4
10,9,24C	33	15.8	14.7	- 7.0	17.3	+ 9.5
15,16,24B	38	20.7	19.3	- 6.8	21.0	+ 1.4
23,24,24A	42	23.7	20.9	-11.8	24.2	+ 2.1
Composite		18.1	16.7	- 7.7	18.9	+ 4.4

TABLE LIX (Continued)

COMPARATIVE COMBINED BOARD PERFORMANCE AT 65% R.H. FOR A-FLUTE COMBINED BOARDS MADE WITH 23- AND 26-LB. EUROPEAN MEDIUM AND 26-LB. DOMESTIC MEDIUM

Runs	US Linerboard Grade Weight	26-lb. Domestic Medium	23-lb. European Medium	Diff., %[a]	26-lb. European Medium	Diff., %[a]
		Edgewise Compression, lb./in. (cross)				
3,4,24D	26	36.5	38.9	+ 6.6	38.3	+ 4.9
10,9,24C	33	41.4	43.6	+ 5.3	44.0	+ 6.3
15,16,24B	38	42.7	45.6	+ 6.8	46.1	+ 8.0
23,24,24A	42	46.9	50.0	+ 6.6	48.1	+ 2.6
Composite		41.9	44.5	+ 6.2	44.1	+ 5.3
		Torsion Tear, in.-oz. (av. in and cross)				
3,4,24D	26	236	200	-15.3	214	- 9.3
10,9,24C	33	264	246	- 6.8	260	- 1.5
15,16,24B	38	298	274	- 8.1	290	- 2.7
23,24,24A	42	296	282	- 4.7	288	- 2.7
Composite		274	250	- 8.8	263	- 4.0
		Torsion Tear, in.-oz. (flap score)				
3,4,24D	26	223	187	-16.1	188	-15.7
10,9,24C	33	234	212	- 9.4	215	- 8.1
15,16,24B	38	260	225	-13.5	233	-10.4
23,24,24A	42	255	235	- 7.8	234	- 8.2
Composite		243	215	-11.5	218	-10.3
		Caliper, pt.				
3, 4, 24D	26	196	192	- 2.0	196	0.0
10, 9, 24C	33	194	193	- 0.5	195	+ 0.5
15, 16, 24B	38	198	194	- 2.0	197	- 0.5
23, 24, 24A	42	199	198	- 0.5	198	- 0.5
Composite		197	194	- 1.5	197	0.0
		Pin Adhesion, lb./4 sq. in.				
3, 4, 24D	26	36	30	-16.7	41	+13.9
10, 9, 24C	33	27	31	+14.8	33	+ 6.3
15, 16, 24B	38	34	35	+ 2.9	38	+ 8.6
23, 24, 24A	42	38	37	- 2.6	37	0.0
Composite		34	33	- 2.9	37	+ 8.8

[a] Based on 26-lb. domestic medium results as reference.

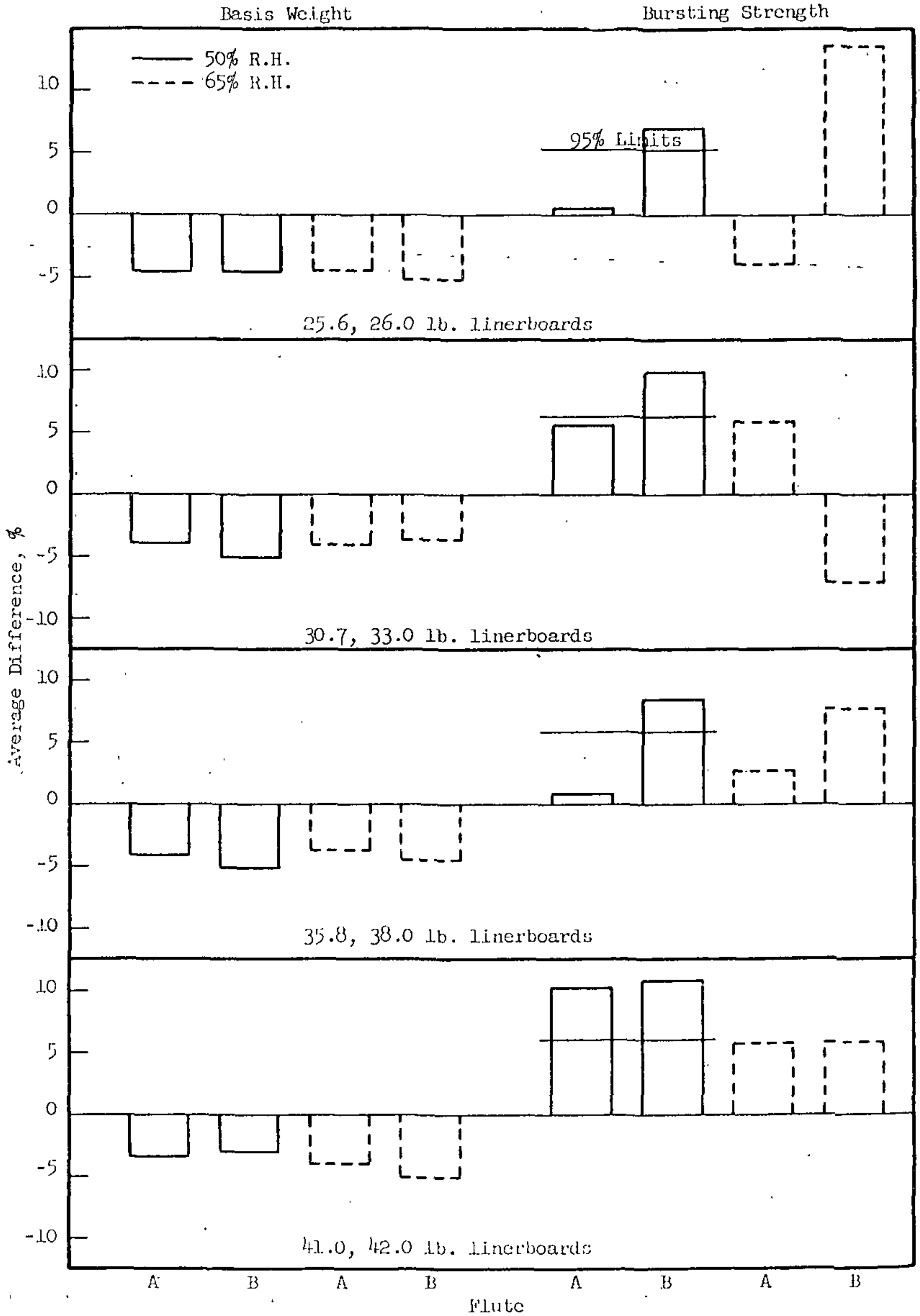


Figure 45. Comparison of the Effect of Type of Medium (26-Lb. U.S. as Reference vs. 23-Lb. European) on Average Difference in Basis Weight and Bursting Strength of Combined Board

Composite Average Difference in Weight, %[a]

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	23-lb. European Semichemical Medium 50% R.H. A-Flute	50% R.H. B-Flute	65% R.H. A-Flute	65% R.H. B-Flute
26.0	-4.6	-4.6	-4.5	-5.2
33.0	-4.0	-5.1	-4.1	-3.7
38.0	-4.2	-5.2	-3.8	-4.5
42.0	-3.4	-3.0	-4.0	-5.1

[a]Combined board made with 26-lb. U.S. semichemical medium used as reference.

When the bursting strength results are considered it may be seen that, with few exceptions, the boards made with 23.0-lb. European medium give higher bursting strengths. The composite average differences at each of the four grade weight levels are shown in the following tabulation and illustrated in Fig. 45.

Composite Average Difference in Bursting Strength, %[a]

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	23-lb. European Semichemical Medium 50% R.H. A-Flute	50% R.H. B-Flute	65% R.H. A-Flute	65% R.H. B-Flute
26.0	+0.5	+7.0	-4.1	+13.6
33.0	+5.7	+9.9	+5.8	+7.4
38.0	+0.8	+8.4	+2.7	+7.6
42.0	+10.1	+10.8	+5.7	+5.7

[a]Combined board made with 26-lb. U.S. semichemical medium used as reference.

It may be seen that the average difference varied from a -4.1 to +13.6. The nature of the difference is believed to be associated with the lower flat crush obtained with the 23.0-lb. European medium.

The flat crush and puncture results tabulated according to type of medium are tabulated in Tables XLIX and L, respectively, for 50 and 65% R.H. For the purpose of comparison the composite average differences in flat crush follow and are illustrated in Fig. 46:

Composite Average Difference in Flat Crush, %[a]

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	23-lb. European Semichemical Medium			
	50% R.H.		65% R.H.	
	A-Flute	B-Flute	A-Flute	B-Flute
26.0	-13.8	-9.5	-12.3	-12.3
33.0	-10.2	-16.5	-9.4	-7.6
38.0	-9.8	-10.7	-5.0	-3.7
42.0	-4.4	-12.2	-3.1	-5.1

[a]Combined board made with 26.0-lb. medium used as reference.

It may be seen that the combined boards made with 26.0-lb. U.S. semi-chemical medium average 3-16% higher in flat crush than the corresponding combined board made with 23-lb. European medium.

The puncture results are also tabulated in Tables XLIX and L for 50 and 65% R.H., respectively. It is well known that the puncture test is markedly influenced by the caliper and flat crush of the combined board. It has just been shown that the flat crush is lower on combined board made with 23.0-lb. European medium and as will be seen later the caliper is also lower. Thus, it is not unexpected that the puncture is in most instances also lower on combined board made with 23.0-lb. European medium. The composite average difference in puncture between board made with 23.0-lb. European medium and 26.0-lb. U.S. medium is shown in the following tabulation and illustrated graphically in Fig. 46.

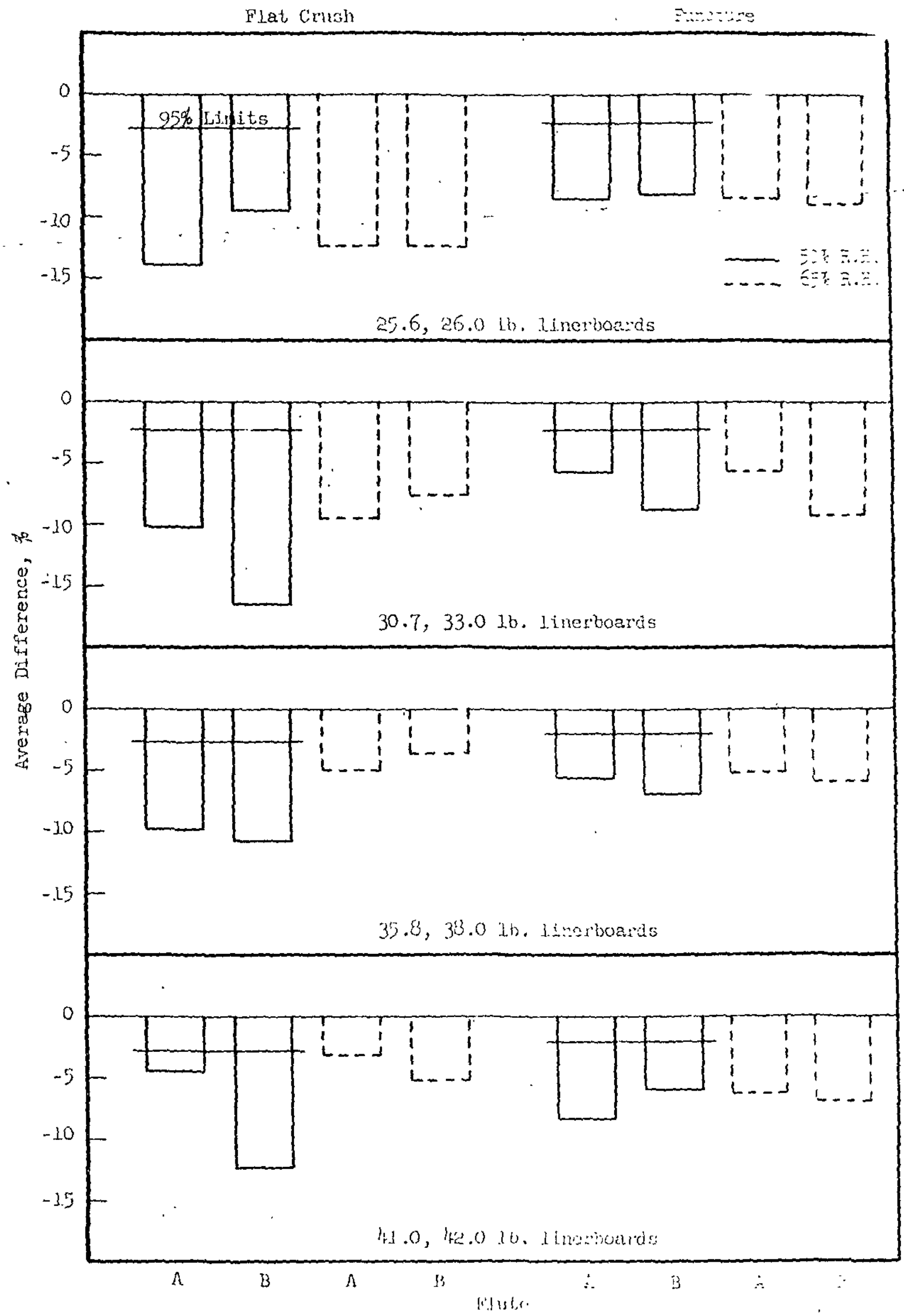


Figure 46. Comparison of the Effect of Type [illegible] (26-lb. [illegible] Reference vs. 23-lb. European) [illegible]

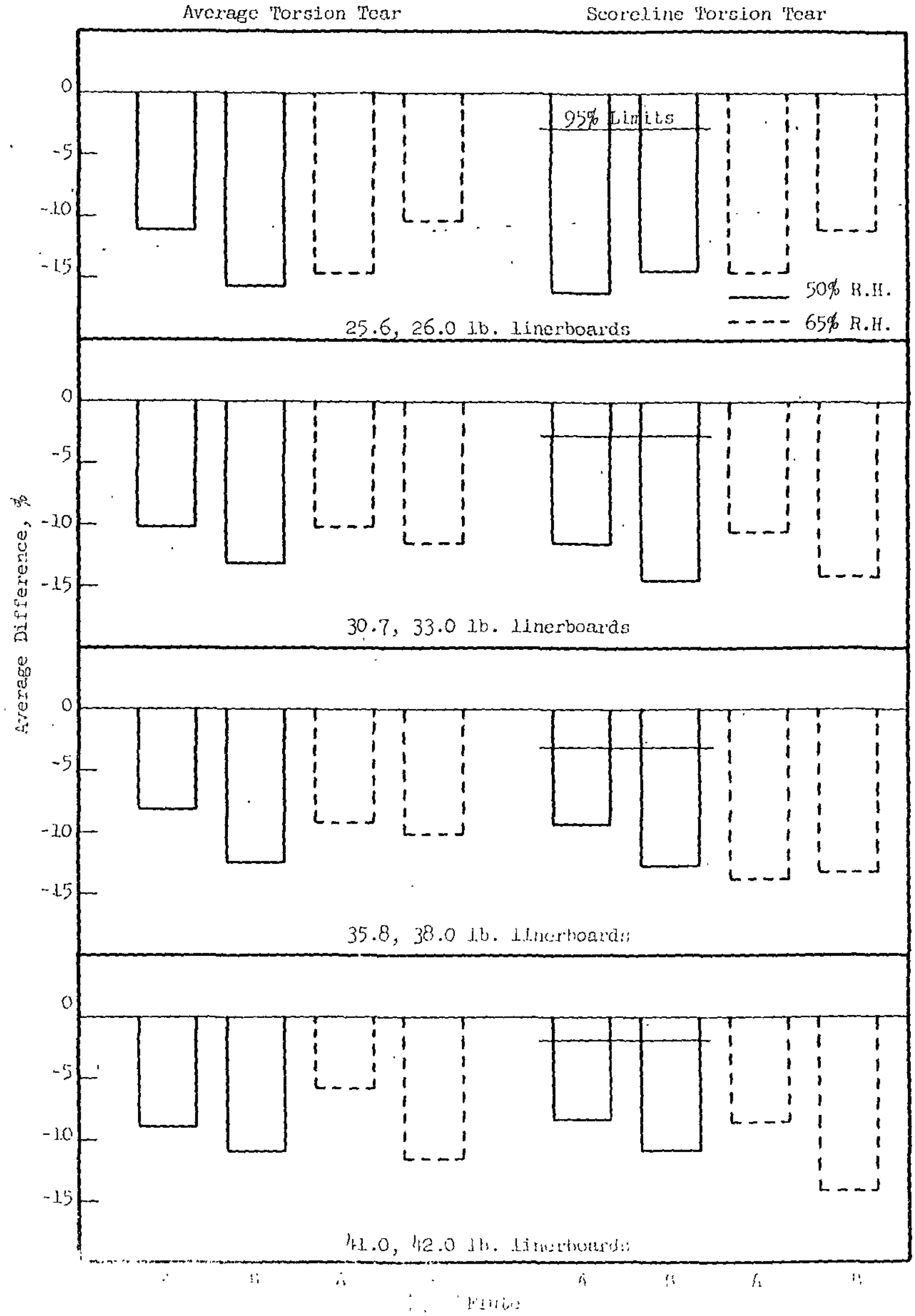
Composite Average Difference in Puncture, %[a]

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	23-lb. European Semichemical Medium			
	50% R.H.		65% R.H.	
	A-Flute	B-Flute	A-Flute	B-Flute
26.0	-8.5	-8.1	-8.5	-8.7
33.0	-5.7	-8.8	-5.6	-9.1
38.0	-5.6	-6.8	-5.1	-5.7
42.0	-8.2	-5.9	-6.1	-6.7

[a]Combined board made with 26.0-lb. U.S. semichemical medium used as reference.

It may be noted that, on the basis of the composite average differences, the combined boards made with 26.0-lb. U.S. semichemical medium exhibit 5.1 to 9.1% higher puncture strength than the combined boards fabricated with 23.0-lb. European semichemical medium.

A comparison of the torsion tear results tabulated in Tables LI and LII for 50 and 65% R.H., respectively, reveals that in practically all instances the combined boards made with 26.0-lb. U.S. medium give higher torsion tear results. This undoubtedly accounts for the higher rough handling performance obtained on the boxes made with 26.0-lb. U.S. medium in contrast to those made with 23.0-lb. European medium. The composite average differences are shown in the following tabulation and graphically illustrated in Fig. 47.



[illegible] Comparison of [illegible] Type [illegible]
Reference vs. 23-lb. European) on average Difference in Torsion
[illegible]

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	Composite Average Diff. in Average Torsion Tear, %[a]		Composite Average Diff. in Scoreline Torsion Tear, %[a]	
	A-Flute	B-Flute	A-Flute	B-Flute
		50% R.H.		
26.0	-11.1	-15.6	-16.6	-14.4
33.0	-10.2	-13.2	-11.5	-14.5
38.0	-8.2	-12.4	-9.3	-12.7
42.0	-8.9	-10.8	-8.3	-10.8
		65% R.H.		
26.0	-14.6	-10.3	-14.5	-11.2
33.0	-10.1	-11.5	-10.6	-14.3
38.0	-9.3	-10.1	-13.7	-13.3
42.0	-5.7	-11.5	-8.5	-14.1

[a]Combined board made with 26.0-lb. U.S. medium used as reference.

The average torsion tear results on unscored boards made with 26.0-lb. U.S. medium are 8-20% higher than on unscored boards made with 23.0-lb. European medium. The corresponding scoreline results on boards made with 26.0-lb. U.S. medium range from 6-15% higher than the corresponding results on boards made with 23.0-lb. European medium.

The caliper and flexural stiffness results, the latter expressed as the geometric mean, are given in Tables LIII and LIV, respectively, for 50 and 65% R.H. In most instances the differences in the mean of the flexural stiffness are not great enough to be considered significant. On the other hand, the caliper is higher on the boards made with 26.0-lb. U.S. medium as would be expected. The results are illustrated in Fig. 48.

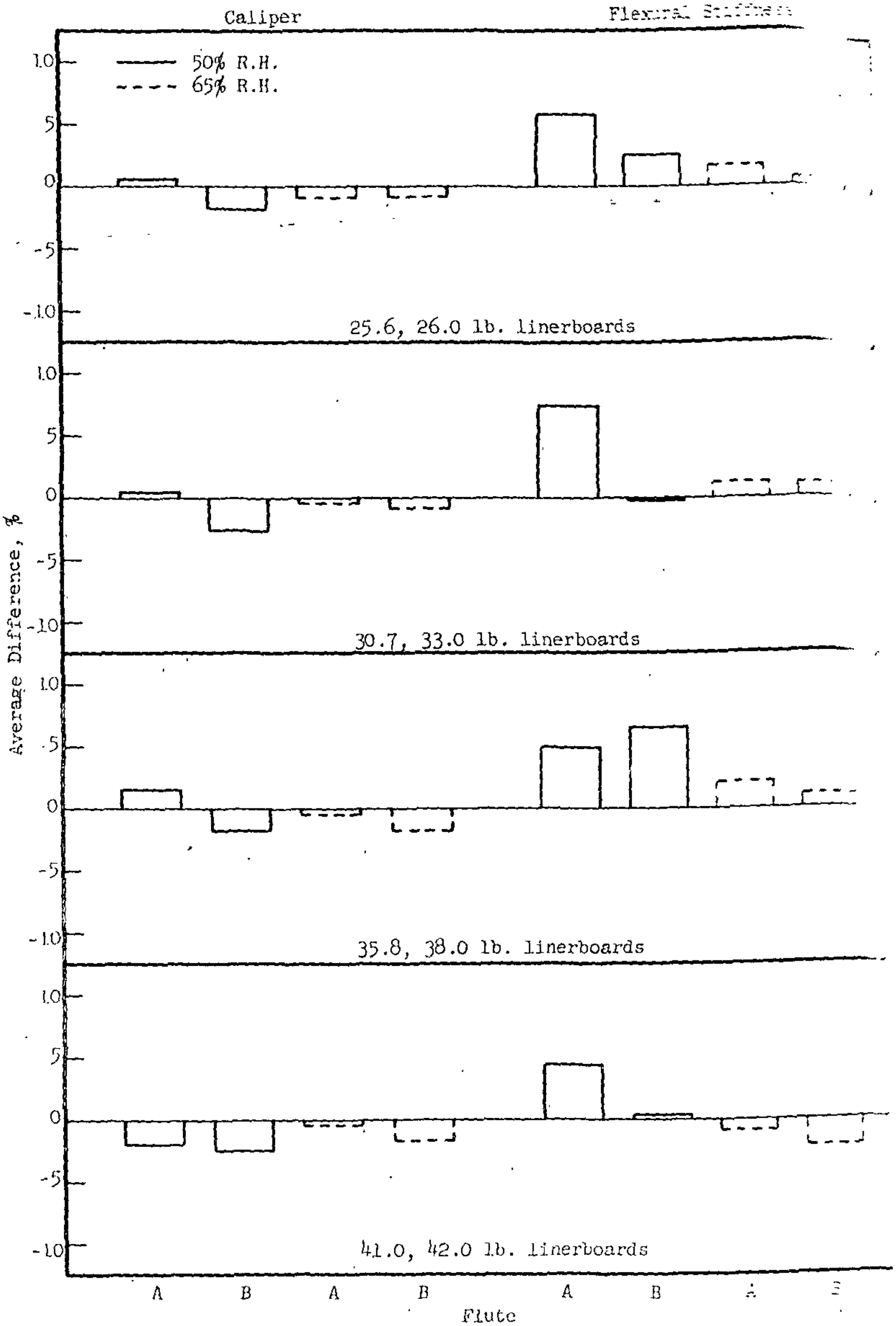


Figure 48. Comparison of the Effect of Type of Medium (26-Lb. U.S. as Reference vs. 23-Lb. European) on Average Difference in ... and $\sqrt{D_1D_2}$ of Combined Board.

From a comparison of the edgewise compression results tabulated in Tables LV and LVI for 50 and 65% R.H., respectively, it may be noted that in general the combined boards fabricated with 26.0-lb. U.S. medium have higher machine-direction edgewise compression strength but lower cross-machine edgewise compression strength than the corresponding combined boards made with 23.0-lb. European medium. As pointed out earlier, the machine direction edgewise compression is the most important combined board property insofar as end-load box compression is concerned. Cross-machine edgewise compression is of equal importance in top-load box compression. It may be recalled that in general the boxes made with 26.0-lb. U.S. medium gave better end-load compression but poorer top-load compression than boxes made with 23.0-lb. European medium. Hence, the edgewise compression strength results show trends, in relation to box compression, that would be anticipated. For the purpose of comparison, the composite average differences in edgewise compression results are given in the following tabulation and illustrated in Fig. 49.

U.S. Linerboard Nominal Weight, (lb./M sq. ft.)	Composite Average Difference In-Machine Direction Edgewise Compression, %[a]		Composite Average Difference in Cross-Machine Edgewise Compression, %[a]	
	A-Flute	B-Flute	A-Flute	B-Flute
		50% R.H.		
26.0	-15.4	-5.3	+8.8	+5.3
33.0	-4.7	-6.9	+9.6	+2.0
38.0	-0.6	-2.2	+5.7	+3.7
42.0	+6.5	-6.9	+7.9	+6.6
		65% R.H.		
26.0	-6.8	-2.1	+6.9	+3.6
33.0	-3.8	-8.9	+5.7	+8.1
38.0	-9.0	-6.4	+7.0	+5.5
42.0	-4.0	-4.1	+6.1	+5.5

[a]Combined board made with 26.0-lb. U.S. medium used as reference.

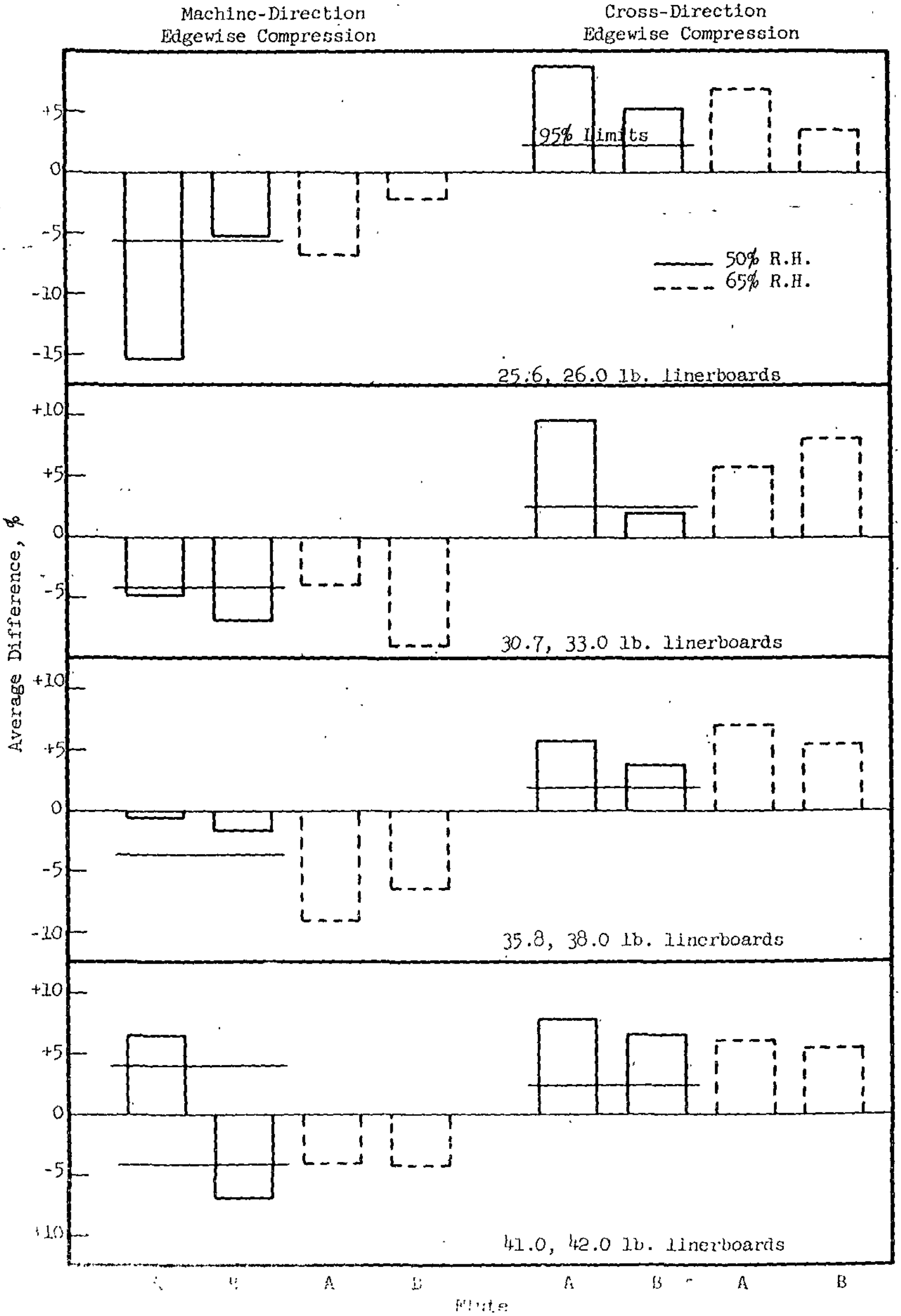


Figure [illegible]. Comparison of the Effect [illegible] Type [illegible] ([illegible] lb. U.S. as Reference vs. 23-lb. European) on Average Difference in [illegible] [illegible]

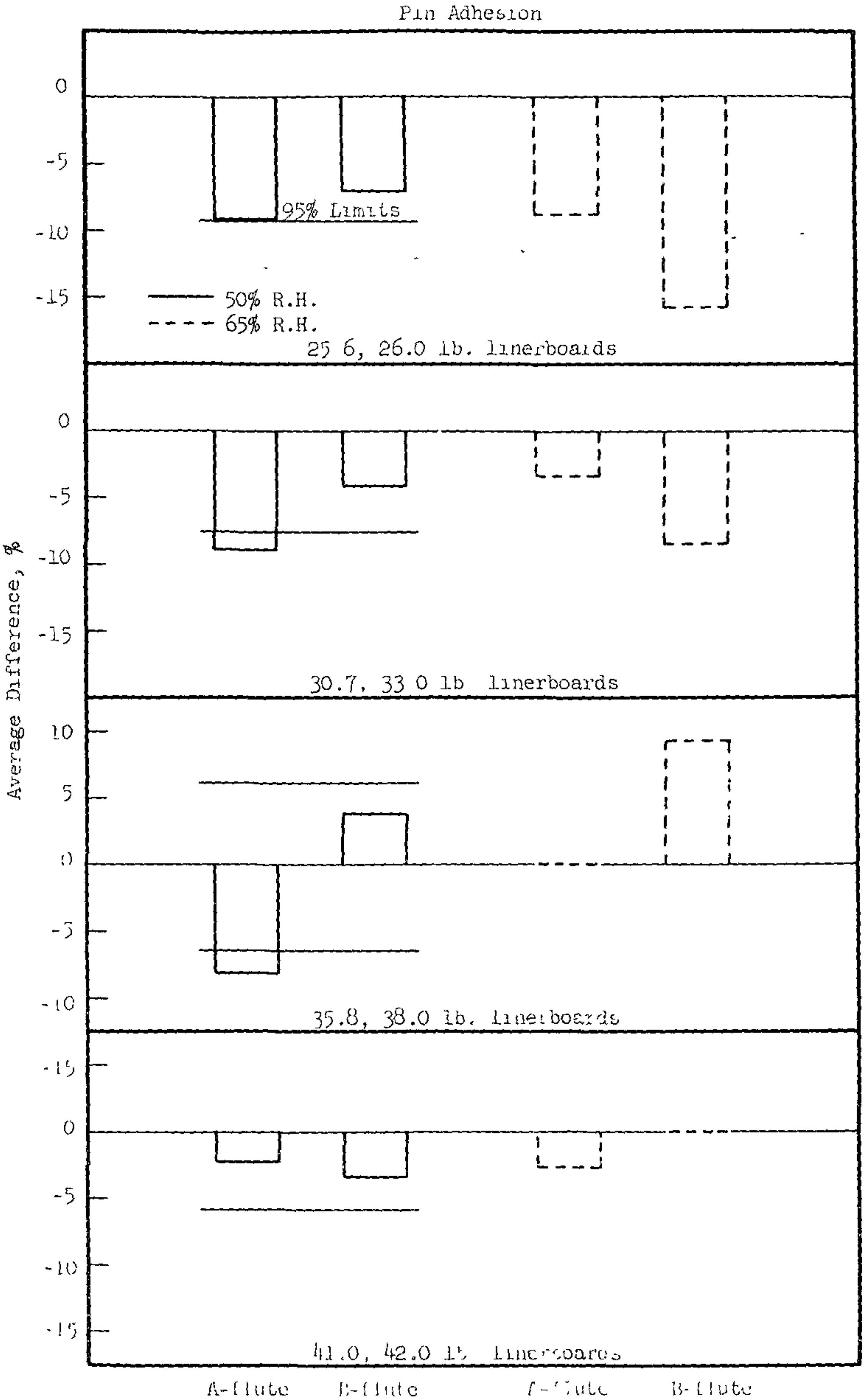
It may be noted from the pin adhesion results tabulated in Table LVII and illustrated in Fig. 50 that, in general, the pin adhesion results are higher for the combined boards made with 26.0-lb. U.S. medium.

It may be recalled that the U.S. linerboards were also fabricated with a sample of 26.0-lb. European medium as well as 23.0-lb. European and 26.0-lb. U.S. medium into A-flute combined board and boxes. The combined board results are tabulated in Table LVIII and LIX for 50 and 65% R.H., respectively. As would be expected, the average weight of the combined boards fabricated with 26.0-lb. U.S. medium is not significantly different from that of the corresponding boards made with 26.0-lb. European medium but averages approximately 4% higher than that of the combined boards fabricated with 23.0-lb. European medium. The composite average differences are given in the following tabulation:

Composite Average Differences[a], %

Test Property	23.0-lb. European Medium 50% R.H.	23.0-lb. European Medium 65% R.H.	26.0-lb. European Medium 50% R.H.	26.0-lb. European Medium 65% R.H.
Basis weight	-4.3	-4.2	0.0	0.0
Caliper	-1.0	-1.5	+1.0	0.0
Bursting strength	+6.8	+4.4	0.0	+0.9
Puncture	-5.7	-5.8	+2.4	+1.0
Flat crush	-9.5	-8.6	+1.1	+7.7
Flexural stiffness ($\sqrt{D_x D_y}$)	+3.6	+1.0	+8.5	+0.4
Edgewise compression, MD	-4.3	-7.7	+12.2	+4.4
Edgewise compression, CD	+5.9	+6.2	+8.2	+5.3
Torsion tear, av. MD and CD	-10.4	-8.8	-5.2	-4.0
Torsion tear, score line	-13.4	-11.5	-8.8	-10.3
Pin adhesion	-7.3	-2.9	-2.5	+8.8

[a]Combined board made with 26.0-lb. U.S. medium used as reference.



[illegible] 50. Comparison of [illegible] from (26-lb. [illegible]

In general, the average bursting strength results on the combined boards made with 26.0-lb. U.S. medium are not significantly different from the corresponding results on the combined boards made with 26.0-lb European medium. On the other hand, the combined boards made with 23 0-lb European medium give higher average bursting strength results than the corresponding boards made with 26.0-lb. U.S. medium, the average differences being about 7 and 4% at 50 and 65% R.H., respectively. It is believed that the difference in bursting strength is associated with the lower flat crush of the boards made with 23 0-lb. European medium

When the puncture results are considered, it may be observed that at both 50 and 65% R.H. the combined boards made with 26.0-lb U.S. medium exhibit higher puncture strength than the corresponding combined boards made with 23 0-lb European medium. On the other hand, at both 50 and 65% R.H., the boards made with 26 0-lb. U.S. medium exhibit approximately the same puncture strength as the corresponding boards fabricated with 26 0-lb European medium The trends noted above are believed to be associated with differences in flat crush and weight.

As may be seen in Tables LVIII and LIX, the combined boards made with 26 0-lb. U.S. medium have slightly lower flat crush strength than the corresponding boards made with 26 0-lb European but higher flat crush than the combined boards made with 23 0-lb. European medium

The flexural stiffness expressed as the geometric mean for the combined board made with 26-lb U S medium is lower at 50% R.H. for the combined board made with 26-lb U.S. medium than for the corresponding samples made with 23 0-lb. and 26 -lb. European medium, at 65% R H , however, the differences are not considered significant It may be recalled that flexural stiffness is one of the basic properties of the combined board which governs box compression

The average machine-direction edgewise compression strength for the combined boards made with 26.0-lb. U.S. medium are higher (4 to 8%) than the corresponding results for the combined boards made with 23.0-lb. European medium but lower (4 to 12%) than those for the combined boards made with 26.0-lb. European medium. As noted earlier, machine-direction edgewise compression is important because it has been found to be the major combined board property governing end-load box compression. In this connection it may be recalled that the boxes made with 26.0-lb. U.S. medium gave higher end-load compression than the corresponding boxes made with 23.0-lb. European medium but lower end-load compression than the corresponding boxes fabricated with 26.0-lb. European medium. As noted earlier, cross-machine edgewise compression is important because it has been found to be the major combined board property governing top-load compression. It may be noted that the cross-machine edgewise compression results for combined boards made with 26.0-lb. U.S. medium are lower than the corresponding results for boards made with 23.0-lb. European medium and also for the boards made with 26.0-lb. European medium. It may be recalled that the top-load box compression results show a similar trend.

The torsion tear results on the combined boards made with 26.0-lb. U.S. medium are higher than the corresponding results on the boards made with either the 23.0 or 26.0-lb. European medium. The results for the 26.0-lb. European medium in turn were higher than those for the 23.0-lb. European medium. It may be recalled that the same general trend was observed for the rough handling box performance. These trends indicate that since the same linerboards were involved it would appear that the U.S. medium has higher tearing strength and stretch characteristics than the European mediums. As will be shown later, this is the case. The European mediums are made primarily from birch in contrast to the U.S. medium used herein which was made primarily from gum. The longer fiber length of the U.S. medium probably accounts for the difference in rough handling performance of the boxes.

The comparative performance of combined boards fabricated with 26.0 and 23.0-lb. European medium and 26.0-lb. U.S. medium may be summarized as follows:

1. There is no significant difference in bursting and puncture strength between boards made with 26-lb. U.S. and 26-lb. European mediums. On the other hand, the combined boards made with 23.0-lb. European medium exhibit 4-7% higher bursting strength and 5-6% lower puncture than the corresponding combined boards made with 26.0-lb. U.S. medium.

2. Flat crush results on combined boards made with 26.0-lb. U.S. medium are slightly lower than the corresponding results for combined boards made with 26.0-lb. European medium but 8-9% higher than the results for the corresponding combined boards made with 23.0-lb. European medium.

3. Flexural stiffness of the combined boards made with 26.0-lb. U.S. medium is lower than that of the corresponding combined boards made with 23.0 and 26.0-lb. European mediums. It is doubtful whether the observed differences are significant in more than a few instances, however.

4. The machine and cross-machine edgewise compression results for the combined boards made with 26.0-lb. U.S. medium are lower (machine direction 4-12%, cross-machine direction 5-8%) than the results for the corresponding samples made with 26.0-lb. European medium. The cross-machine direction results for the combined board fabricated with 23.0-lb. European medium are 5-6% higher, and the machine direction results 4-8% lower, than the results for the combined board made with 26.0-lb. U.S. medium.

5. The combined boards made with 26.0-lb. U.S. medium are higher in torsion tear - average and scoreline - than the corresponding samples made with either 23.0 or 26.0-lb. European mediums.

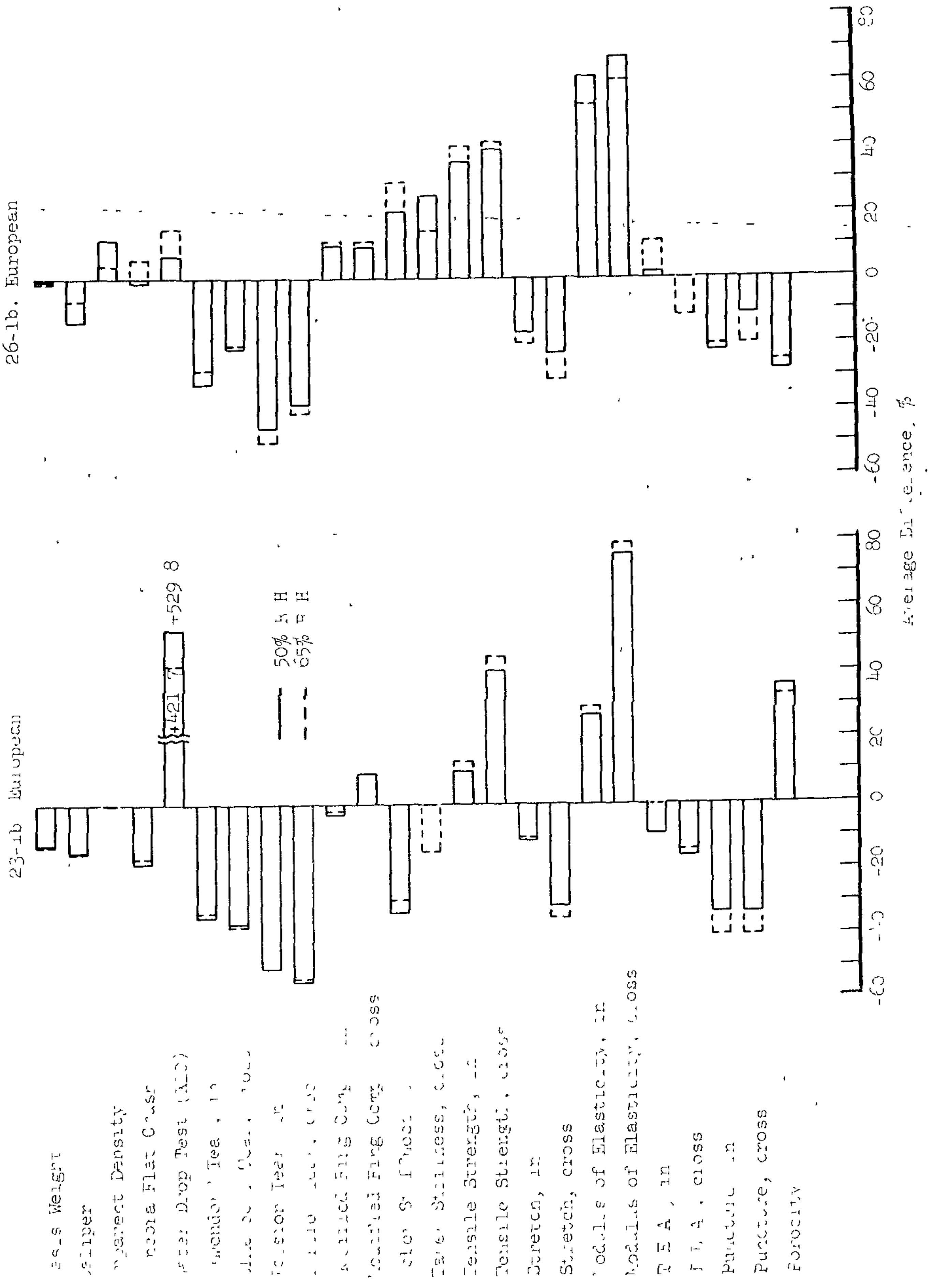
6. In general, combined board made with 26.0-lb. European medium gives results comparable to combined board made with similar weight U.S. medium except for possibly flat crush and edgewise compression strength which are slightly higher and torsion tear strength which is slightly lower.

C. Comparison of Physical Properties of U.S. and European Corrugating Mediums

During the fabrication of the fifty-two different combinations, samples of the corrugating medium were taken at the "start" and "end" of each set of "runs" involving a given type of medium. The samples taken at the "start" and "end" were evaluated separately for each series of runs and then averaged to characterize the respective materials. The results obtained for the various runs are tabulated in Tables LX and LXI, respectively, for 50 and 65% R.H. The per cent differences in physical properties are summarized in Tables LXII and LXIII, respectively, for 50 and 65% R.H., and illustrated in Fig. 51.

It may be noted that the respective mediums were only slightly higher in basis weight than their nominal grade weights. Although the U.S. medium is higher in basis weight, the caliper of the 23.0-lb. European medium is correspondingly lower; thus, the apparent densities are approximately equivalent. In contrast, the caliper of the 26.0-lb. European medium is approximately 14% lower than that of the 26.0-lb. U.S. medium resulting in a higher density for the former.

When the Concora flat crush characteristics of the mediums are considered it may be seen that the U.S. medium exhibits a 16 to 17% higher flat



Physical Properties of European and U S

TABLE IX

PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC CORRUGATING MEDIUMS USED IN FABRICATION AT 50% R.H.

Runs	Flute	Roll No.	Weight, lb./M sq. ft.	Caliper, pt.	App. Density	Concora Flat Crush, p.s.i.	Water Drop, sec.	Elmendorf Tear, g./sheet In	Elmendorf Tear Cross	Elmendorf Tear Av.	Torsion Tear, in.-oz. In	Torsion Tear Cross.	Torsion Tear Av.	Modified Ring Compression, lb./in. In	Modified Ring Compression Cross	Taber Stiffness, g.-cm. In	Taber Stiffness Cross	Tensile, lb./in. In	Tensile Cross	Stretch, % In	Stretch Cross	Modulus of Elasticity, p.s.i. x 10^3 In	Modulus of Elasticity Cross	TEA, in.-lb. sq. in. In	TEA Cross	Puncture, unit In	Puncture Cross	Puncture Av.	Porosity, sec./100 cc
23 lb. European Medium																													
1,4,5	A	21	23.4	9.0	2.6	32.6	579+	62	78	70	12	12	12	17.1	14.2	11	8	52.4	27.4	1.6	1.6	647	388	.51	.30	5	6	6	32
5	A	21	23.7	9.1	2.6	33.6	600+	64	79	71	12	12	12	17.3	14.6	11	8	53.0	27.6	1.6	1.7	640	380	.54	.32	6	6	6	37
8,12	A	21	23.6	9.0	2.6	33.5	600+	66	78	71	11	12	12	17.4	14.8	10	10	52.2	27.0	1.6	1.7	638	377	.54	.32	6	6	6	38
13,16	A	21	23.5	8.8	2.6	33.8	600+	64	75	70	11	12	12	17.7	14.4	10	9	51.4	27.2	1.6	1.7	646	390	.54	.32	6	6	6	38
17,20,21,24	A	21	23.9	9.0	2.6	34.4	600+	64	76	70	12	12	12	18.0	14.2	10	9	52.0	28.0	1.6	1.8	644	386	.56	.36	6	6	6	39
Av.			23.6	9.0	2.6	33.5	596+	64	77	70	12	12	12	17.5	14.4	10	9	52.2	27.4	1.6	1.7	643	384	.54	.32	6	6	6	37
1,4,5	B	20	23.2	9.0	2.6	31.6	600+	66	78	72	12	12	12	16.7	13.6	11	7	49.8	26.3	1.6	1.8	626	360	.50	.32	6	6	6	22
5,9,12	B	20	22.6	8.8	2.6	30.6	600+	62	74	68	12	12	12	16.5	13.4	10	6	50.8	25.8	1.6	1.7	636	365	.52	.31	5	6	6	28
13,16,17	B	20	22.4	8.7	2.6	30.2	600+	58	70	64	12	12	12	17.1	13.6	10	6	51.0	25.8	1.6	1.8	633	367	.52	.32	5	5	5	34
20R,21,24	B	20	22.6	8.8	2.6	30.4	548+	61	72	67	12	12	12	16.6	13.8	10	6	51.4	26.1	1.6	1.8	614	356	.55	.34	5	5	5	38
Av			22.7	8.8	2.6	30.7	587+	62	74	68	12	12	12	16.7	13.6	10	6	50.8	26.0	1.6	1.8	627	362	.52	.32	5	6	6	30
Grand av.			23.2	8.9	2.6	32.2	592+	63	76	69	12	12	12	17.1	14.0	10	8	51.5	26.7	1.6	1.8	635	373	.53	.32	6	6	6	34
26 lb. U. S. Medium																													
2,3	A	41	26.4	10.5	2.5	39.4	102	96	120	108	24	26	25	17.4	13.0	14	8	46.8	18.6	1.8	2.5	502	207	.56	.34	9	9	9	26
6,7	A	41	26.4	10.4	2.6	39.8	87	96	118	108	23	26	24	17.4	13.2	14	7	47.4	19.0	1.8	2.7	508	213	.58	.39	9	9	9	27
10,11	A	41	26.5	10.4	2.6	39.5	90	99	117	108	24	26	25	17.8	13.2	14	8	47.9	19.2	1.9	2.8	506	215	.60	.41	9	9	9	27
14,15	A	41	26.5	10.4	2.6	39.0	92	98	119	108	24	26	25	17.9	12.6	14	9	46.8	19.2	1.8	2.7	502	220	.58	.40	9	10	10	25
18,19,22,23	A	41	26.4	10.4	2.6	39.8	98	94	121	108	23	25	24	17.7	12.6	15	8	45.5	19.0	1.8	2.8	492	218	.56	.42	9	10	10	25
Av.			26.4	10.4	2.6	39.5	94	97	119	108	24	26	25	17.6	12.9	14	8	46.9	19.0	1.8	2.7	502	215	.58	.39	9	9	9	26
2,3,6,7	B	40	26.5	10.5	2.5	38.6	108	96	118	107	24	26	24	17.2	12.2	16	7	47.3	18.5	1.8	2.4	506	206	.55	.36	9	9	9	22
10,11	B	40	26.5	10.5	2.5	38.8	96	94	122	108	24	26	26	17.5	12.6	16	7	46.1	18.8	1.8	2.5	488	208	.56	.36	9	9	9	24
14,15,18,19	B	40	26.4	10.4	2.5	39.2	90	92	120	107	24	27	26	17.6	12.8	16	7	46.2	19.0	1.8	2.7	490	210	.58	.39	9	9	9	25
22,23	B	40	26.6	10.2	2.6	38.7	84	93	120	106	25	26	26	18.2	13.0	16	7	47.4	19.2	1.8	2.8	509	215	.58	.42	9	9	9	24
Av.			26.5	10.1	2.5	38.8	94	94	120	107	24	26	26	17.6	12.6	16	7	46.9	18.9	1.8	2.6	498	210	.57	.38	9	9	9	24
Grand av.			26.4	10.4	2.6	39.2	94	96	120	108	24	26	26	17.6	12.8	15	8	46.9	19.0	1.8	2.6	500	212	.58	.38	9	9	9	25
26 lb. European Medium																													
24A,B,C,D	A		26.3	9.0	2.9	38.6	100	65	94	80	13	16	14	19.3	14.0	18	10	63.4	26.4	1.5	2.0	804	355	.59	.38	7	8	8	18

TABLE LXI

PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC CORRUGATING MEDIUMS USED IN FABRICATION AT 65% R H

Runs	Flute	Roll No	Weight, lb /M sq. ft	Caliper, pt	Apparent Density	Concora Flat Crush, p s.i.	Water Drop, sec	Elmendorf Tear, g./sheet In	Elmendorf Tear, g./sheet Cross	Elmendorf Tear, g./sheet Av	Torsion Tear, in -oz. In	Torsion Tear, in -oz. Cross	Torsion Tear, in -oz. Av	Modified Ring Compression, lb /inch In	Modified Ring Compression, lb /inch Cross	Taber Stiffness, g -cm. In	Taber Stiffness, g -cm. Cross
23-lb. European Medium																	
1,4,5	A	21	23.8	8.6	2.8	26.4	600+	75	88	81	16	16	16	16.6	13.0	10	7
8,	A	21	24.1	8.6	2.8	28.0	600+	76	90	82	16	16	16	16.8	13.1	10	7
9,12	A	21	24.2	9.1	2.6	27.5	600+	74	89	82	16	16	16	17.0	13.2	10	7
13,16	A	21	23.9	9.4	2.5	26.6	600+	74	86	80	15	16	16	16.8	13.2	10	7
17,20,21,24	A	21	24.0	9.2	2.6	28.0	600+	74	88	81	15	16	16	16.6	13.0	10	8
Av			24.0	9.0	2.7	27.3	600+	75	88	81	16	16	16	16.8	13.1	10	7
1,4,5	B	20	23.6	9.1	2.6	26.0	600+	78	90	84	16	16	16	15.8	12.1	11	6
8,9,12	B	20	23.0	8.9	2.6	25.2	600+	74	85	80	16	15	16	15.7	12.5	10	6
13,16,17	B	20	22.8	8.8	2.6	25.0	600+	70	83	76	16	15	16	15.5	12.4	10	6
20R,21,24	B	20	22.8	8.8	2.6	25.4	600+	70	82	76	15	16	16	15.6	12.4	10	6
Av			23.0	8.9	2.6	25.4	600+	73	85	79	16	16	16	15.6	12.4	10	6
Grand Av			23.5	9.0	2.6	26.4	600+	74	86	80	16	16	16	16.2	12.8	10	6
26-lb. US Medium																	
2,3	A	41	26.6	10.4	2.6	30.4	88	110	136	123	33	34	34	16.4	11.8	14	8
6,7	A	41	26.8	10.4	2.6	31.6	100	112	137	124	32	33	33	16.8	11.8	14	7
10,11	A	41	26.8	10.6	2.6	33.0	102	112	139	126	31	34	32	16.8	11.8	14	8
14,15	A	41	26.8	10.6	2.6	32.2	128	113	138	126	32	34	32	16.4	11.4	14	8
18,19,22,23	A	41	26.9	10.4	2.6	31.4	134	112	138	125	32	34	32	16.2	11.3	15	8
Av			26.8	10.5	2.6	31.7	110	112	138	125	32	34	33	16.5	11.6	14	8
2,3,6,7	B	40	27.0	10.6	2.6	31.2	140	110	137	124	32	34	34	16.7	11.7	16	6
10,11	B	40	27.0	10.5	2.6	31.7	94	109	136	122	33	34	34	16.6	11.8	15	6
14,15,18,19	B	40	26.8	10.5	2.6	31.0	120	110	135	122	33	35	34	16.2	11.8	15	6
22,23	B	40	26.8	10.5	2.6	32.0	124	110	138	124	33	34	34	16.6	11.8	15	6
Av			26.9	10.5	2.6	31.5	120	110	136	123	33	34	34	16.5	11.8	15	6
Grand Av			26.8	10.5	2.6	31.6	115	111	137	124	32	34	34	16.5	11.7	14	7
26-lb European Medium																	
24,B,C,D	A		26.4	9.8	2.7	33.3	132	80	109	94	16	20	18	18.3	13.0	18	8

TABLE LXI (Continued)

PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC CORRUGATING MEDIUMS USED IN FABRICATION AT 65% R.H.

Runs	Flute	Roll No.	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross	Modulus of Elasticity, p.s.i. x 10^3 In	Modulus of Elasticity, p.s.i. x 10^3 Cross	T.E.A., in.-lb./sq. in. In	T.E.A., in.-lb./sq. in. Cross	Puncture, units In	Puncture, units Cross	Puncture, units Av.	Porosity, sec./100 cc.
							23-lb. European Medium							
.,4,5	A	21	50.4	25.4	1.8	1.9	640	371	0.58	0.34	6	6	6	31
,	A	21	50.4	25.6	1.8	2.0	642	369	0.57	0.35	6	6	6	36
.12	A	21	50.1	25.6	1.8	2.0	618	352	0.57	0.37	6	6	6	38
3,16	A	21	48.8	25.7	1.8	2.0	572	338	0.56	0.37	6	6	6	37
7,20,21,24	A	21	49.6	26.0	1.8	2.0	586	349	0.58	0.38	6	6	6	38
v.			49.9	25.7	1.8	2.0	612	356	0.57	0.36	6	6	6	36
.4,5	B	20	46.8	24.6	1.6	2.1	588	320	0.50	0.36	6	6	6	19
9,12	B	20	47.8	24.4	1.7	2.2	597	322	0.54	0.38	6	6	6	26
.,16,17	B	20	48.4	24.5	1.8	2.2	602	330	0.56	0.39	6	6	6	32
R,21,24	B	20	49.5	25.0	1.8	2.3	591	330	0.59	0.41	6	6	6	34
.			48.1	24.6	1.7	2.2	594	326	0.55	0.38	6	6	6	28
and Av.			49.0	25.2	1.8	2.1	603	341	0.56	0.37	6	6	6	32
							26-lb. US Medium							
	A	41	43.0	17.2	1.8	3.0	467	189	0.54	0.40	10	10	10	24
	A	41	42.8	17.2	1.8	3.0	473	191	0.54	0.40	10	10	10	26
11	A	41	44.1	17.5	2.0	3.1	470	190	0.57	0.42	10	10	10	26
5	A	41	43.0	17.4	1.9	3.1	456	186	0.54	0.42	10	10	10	24
9,22,23	A	41	42.4	17.4	1.9	3.2	464	192	0.53	0.44	10	10	10	25
			43.1	17.3	1.9	3.1	466	190	0.54	0.42	10	10	10	25
6,7	B	40	43.4	17.6	1.9	3.2	458	184	0.54	0.43	10	10	10	22
1	B	40	43.6	17.5	2.0	3.0	464	193	0.58	0.41	10	10	10	24
5,18,19	B	40	43.4	17.8	2.0	3.2	468	196	0.58	0.45	10	10	10	25
	B	40	43.6	17.7	2.0	3.4	464	190	0.58	0.47	10	10	10	24
			43.5	17.6	2.0	3.2	464	191	9.57	0.44	10	10	10	24
Av.			43.3	17.4	2.0	3.2	465	190	0.56	0.43	10	10	10	24
							26-lb. European Medium							
C,D	A		60.6	24.6	1.6	2.2	708	304	0.62	0.38	8	8	8	18

TABLE LXII

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC CORRUGATING MEDIUMS AT 50% R.H.

Test Property[b]		26 Lb. US Medium	23 Lb. European Medium	Diff., %[a]	26 Lb. European Medium	Diff., %[a]	26 Lb. US Medium	23 Lb. European Medium	Diff., %[a]	26 Lb. European Medium	Diff., %[a]
							Unit Weight Basis				
Basis weight, lb./M sq.ft.		26.4	23.2	-12.1	26.3	-0.4	--	--	--	--	--
Caliper, pt.		10.4	8.9	-14.4	9.0	-13.5	--	--	--	--	--
Apparent density		2.6	2.6	0.0	2.9	+11.5	--	--	--	--	--
Concora flat crush, p.s.i.		39.2	32.2	-17.9	38.6	-1.5	1.48	1.39	- 6.1	1.47	- 0.7
Water drop, sec.		94	592+	+529.8	100	+6.4	--	--	--	--	--
Elmendorf tear, g./sheet	In	96	63	-34.4	65	-32.3	3.64	2.72	-25.3	2.47	-32.1
	Cross	120	76	-36.7	94	-21.7	4.55	3.28	-27.9	3.57	-21.5
	Av.	108	69	-36.1	80	-25.9					
Torsion tear, in.-oz.	In	24	12	-50.0	13	-45.8	0.91	0.52	-42.9	0.49	-46.2
	Cross	26	12	-53.8	16	-38.5	0.98	0.52	-46.9	0.61	-37.8
	Av.	26	12	-53.8	14	-46.2					
Modified ring compression, lb./in.	In	17.6	17.1	-2.8	19.3	+9.7	0.67	0.74	+10.4	0.73	+ 9.0
	Cross	12.8	14.0	+9.4	14.0	+9.4	0.48	0.60	+25.0	0.53	+10.4
Taber stiffness, g.-cm.	In	15	10	-33.3	18	+20.0	--	--	--	--	--
	Cross	8	8	0.0	10	+25.0	--	--	--	--	--
Tensile, lb./in.	In	46.8	51.5	+10.0	63.4	+35.5	1.77	2.22	+25.4	2.41	+36.2
	Cross	19.0	26.7	+40.5	26.4	+38.9	0.72	1.15	+59.7	1.00	+38.9
Stretch, %	In	1.8	1.6	-11.1	1.5	-16.7					
	Cross	2.6	1.8	-30.8	2.0	-23.1					
Modulus of elasticity, p.s.i. x 10^3	In	500	635	+27.0	804	+60.8					
	Cross	212	373	+75.9	355	+67.5					
TEA, in.-lb./sq.in.	In	.58	.53	- 8.6	.59	+ 1.7					
	Cross	.38	.32	-15.8	.38	0.0					
Puncture, unit	In	9	6	-33.3	7	-22.2					
	Cross	9	6	-33.3	8	-11.1					
Porosity, sec./100 cc.		25	34	+36.0	18	-28.0					

[a] Based on U.S. medium results as reference.
[b] Average of A and B-flute results for all runs.

TABLE LXIII

COMPARISON OF PHYSICAL CHARACTERISTICS OF EUROPEAN AND DOMESTIC CORRUGATING MEDIUMS AT 65% R.H.

Test Property[b]		26 lb. US Medium	23 lb. Eur. Medium	Diff., %[a]	26 lb. Eur. Medium	Diff., %[a]	26 lb. US Medium	23 lb. Eur. Medium	Diff., %[a]	26 lb. Eur. Medium	Diff., %[a]
							Unit Weight Basis				
Basis weight, lb./M sq. ft.		26.8	23.5	-12.3	26.4	-1.5	--	--	--	--	--
Caliper, pt.		10.5	9.0	-14.3	9.8	-6.7	--	--	--	--	--
Apparent density		2.6	2.6	0.0	2.7	+3.8	--	--	--	--	--
Concora flat crush, p.s.i.		31.6	26.4	-16.5	33.3	+5.4	1.18	1.12	-5.1	1.26	+6.8
Water drop, sec.		115	600+	+421.7	132	+14.8	4.29	25.53	+495.1	5.00	+16.6
Elmendorf tear, g./sheet	In	111	74	-33.3	80	-27.9	4.14	3.15	-23.9	3.03	-26.8
	Cross	137	86	-37.2	109	-20.4	5.11	3.66	-28.4	4.13	-19.2
	Av.	124	80	-35.5	94	-24.2					
Torsion tear, in.-oz.	In	32	16	-50.0	16	-50.0	1.19	0.68	-42.9	0.61	-48.7
	Cross	34	16	-52.9	20	-41.2	1.27	0.68	-46.5	0.76	-40.2
	Av.	34	16	-52.9	18	-47.1					
Mod. ring compression, lb./in.	In	16.5	16.2	-1.8	18.3	+10.9	0.62	0.69	+11.3	0.69	+11.3
	Cross	11.7	12.8	+9.4	13.0	+11.1	0.44	0.54	+22.7	0.49	+11.4
Taber stiffness, g-cm.	In	14	10	-28.6	18	+28.6	--	--	--	--	--
	Cross	7	6	-14.3	8	+14.3	--	--	--	--	--
Tensile, lb./in.	In	43.3	49.0	+13.2	60.6	+40.0	1.62	2.09	+29.0	2.30	+42.0
	Cross	17.4	25.2	+44.8	24.6	+41.4	0.65	1.07	+64.6	0.93	+43.1
Stretch, %	In	2.0	1.8	-10.0	1.6	-20.0					
	Cross	3.2	2.1	-34.4	2.2	-31.2					
Mod. of elasticity, p.s.i. x 10^3	In	465	603	+29.7	708	+52.3					
	Cross	190	341	+79.5	304	+60.0					
T.E.A., in.-lb./sq. in.	In	0.56	0.56	0.0	0.62	+10.7					
	Cross	0.43	0.37	-14.0	0.38	-11.6					
Puncture, unit	In	10	6	-40.0	8	-20.0					
	Cross	10	6	-40.0	8	-20.0					
Porosity, sec./100 cc.		24	32	+33.3	18	-25.0					

[a]Based on US medium results as reference.
[b]Average of A- and B-flute results.

crush than the 23 0-lb European medium; however, on a flat crush per unit weight basis,, the difference is only 5 to 6% because of the lower basis weight of the 23.0-lb. European medium The U S and European 26.0-lb. mediums are approximately equal in Concora flat crush on both an actual and unit weight basis On the basis of the Concora flat crush results it would be anticipated that the combined board made with U.S medium would give flat crush results higher than combined board made with 23 0-lb. European medium but approximately the same as the 26.0-lb European medium. As may be recalled, this was generally the case

One of the salient features of corrugated board as a packaging material is its high strength-to-weight ratio made possible by its fluted structure The mechanical properties of a fluted or cellular structure such as corrugated board are dependent on good bonding of the component parts. Because of the severe time limitations encountered in the corrugating operation, the medium-adhesive interaction is important in corrugating. The water drop test is used extensively as a measure of the potential bonding behavior of corrugating medium, although the test leaves much to be desired by way of measuring properties of medium which govern bonding. Water absorption, as measured by the water drop test, is the time required for a measured quantity of water, applied to the surface under specified conditions, to be absorbed by the medium. The longer the time interval, the greater is the resistance to absorption.

It may be seen that the water drop "number" for U.S. medium is about fourfold lower than for 23 0-lb European medium, but only slightly lower than for 26.0-lb European medium. The results indicate that the 23 0-lb European medium probably will be more difficult to bond, especially at high speeds, than the U.S. medium As was pointed out earlier, lower adhesion strength was obtained on the combined board made with 23 0-lb European medium than was obtained ...

same corrugating speed on the combined board made with 26.0-lb. U.S. medium. A higher water drop is believed to be responsible although the European mediums also exhibited wide variations in moisture which may have contributed to the poorer bonding.

When the strength properties are compared, it may be observed that the U.S. medium is higher in Elmendorf tearing strength, stretch, puncture, and torsion tear than the European mediums, the differences being greater for the 23.0-lb. European medium than for the 26.0-lb. European medium. These properties, along with T.E.A., are generally considered to be properties of the medium which are involved in rough handling performance; thus, it would be anticipated that the U.S. medium would be a better medium from the standpoint of rough handling. It may be recalled that the boxes made with U.S. medium did give markedly better rough handling performance. Also, the T.E.A., energy absorption, is generally higher for the U.S. medium than the European mediums.

The modified ring compression, tensile, and modulus of elasticity results are generally lower for the U.S. medium than for the European mediums. These test properties are generally associated with compression performance; thus, the European mediums exhibit more favorable compression properties. The U.S. medium, however, exhibits Taber stiffness higher than the 23.0-lb. European medium but lower than the 26.0-lb. European medium. This is related to box compression but is of secondary importance, in this regard, to tests such as the modified ring compression test.

The porosity results for the U.S. medium are about the same as those for the 26.0-lb. European medium but are lower than those for the 23.0-lb. European medium. This may be another reason for the poorer adhesion of the 23.0-lb. European medium in view of the fact that the lower the porosity test results, the more porous the sheet.

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